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Site Study for Proposed Landfarm

Fort Benning, GA

by
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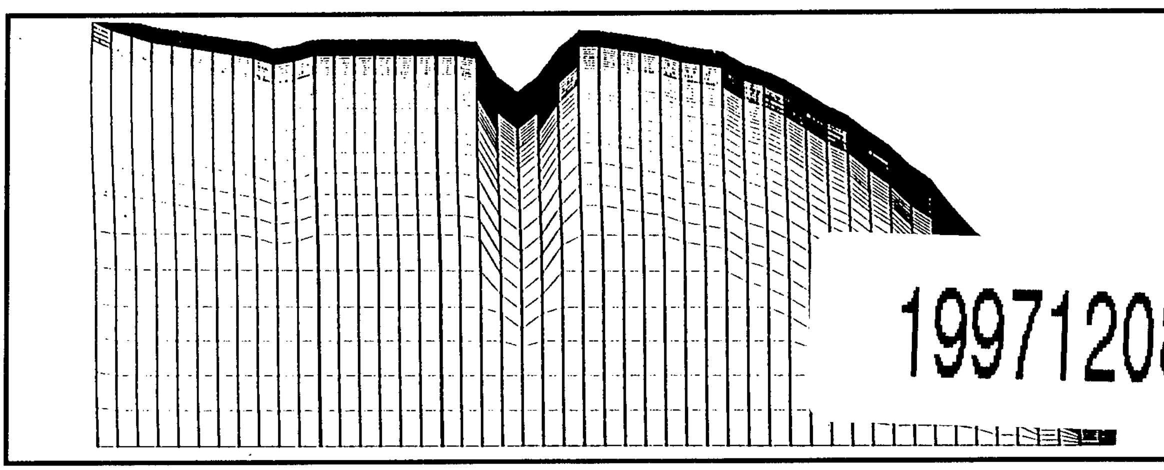

Soil contaminated with petroleum, oil, and lubricants (POL) is often a problem at U.S. Army installations because of underground storage tanks (USTs) of questionable integrity, equipment leaks, and spills during operations and training. Landfarming is a soil-treatment option that capitalizes on the use of bacteria, which are especially adept at mediating biodegradation of compounds common to petroleum fuels, as a way of cleaning the soil. Microbial decomposition of POL contaminants results in fertile, useable soil and reduces monitoring, maintenance, and cost of landfilling.

Fort Benning has been exploring the feasibility of a landfarm as a proactive technology to assure preparedness for spills and leaks that contaminate soil with POL. Preliminary studies led to the selection of a prospective landfarm site. Detailed studies and hydrogeological modeling of the proposed landfarm site followed. This research verified the selected site's positive features for treating POL contaminated soil and explored weaknesses that designing would have to ameliorate.

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Executive Summary

Soil contaminated with petroleum, oil, and lubricants (POL) is often a problem at U.S. Army installations because of underground storage tanks (USTs) of questionable integrity, equipment leaks, and spills during operations and training. Landfarming is a soil-treatment option that capitalizes on the use of bacteria, which are especially adept at mediating biodegradation of compounds common to petroleum fuels, as a way of "cleaning" the soil. Microbial decomposition of POL contaminants results in fertile, useable soil and reduces monitoring, maintenance, and cost of landfilling.

Fort Benning has been exploring the feasibility of a landfarm as a proactive technology to assure preparedness for spills and leaks that contaminate soil with POL. Preliminary studies led to the selection of a prospective landfarm site. Detailed studies and hydrogeological modeling of the proposed landfarm site followed. This research verified the selected site's positive features for treating POL contaminated soil and explored weaknesses that designing would have to ameliorate.

Because the landfarm site consists of typically permeable Coastal Plain sediments, the concern is possible mobilization of landfarm contaminants by infiltrating rainwater that might reach the water table in significant concentrations. Even poor quality soils similar to those at Fort Benning have the ability to greatly reduce petroleum concentration through retardation and biodegradation. However, to ensure no migration of even small amounts of contamination during extreme weather conditions, the landfarm design includes levees around the site, sloping of the site to a catchment basin, and a geosynthetic clay liner under the five treatment areas and a catchment basin. Clay is present in the soil at the site and a clay lens may underlie the site. The site is suitable for a landfarm because of its distance to groundwater and the slow speed at which contaminants would travel in the unsaturated zone.

Design for the proposed site includes five treatment areas of approximately 1 acre each with a total assimilative capacity of 119,790 lb

(almost 60 tons) per year for oily wastes at a 1 percent loading rate; the estimated yearly average of oily contaminate soil needing treatment at Fort Benning is 50 tons. The total area of the landfarm site encompasses approximately 20 acres, providing area for retention pond, buffer strips, building(s), equipment storage, and maneuvering space for equipment.

The life expectancy of landfarm is over 10 years (based on the landfarm established at Fort Polk in 1986 that is still operational). Design features, monitoring, and sound operation of the proposed Fort Benning Landfarm should ensure a life expectancy equal to or greater than the successful Fort Polk landfarm.

Foreword

This study was conducted for Fort Benning Directorate of Public Works under Military Interdepartmental Purchase Request (MIPR) No. 5FDPW10048, Work Unit YH6, "Landfarm Technology at Fort Benning, GA." The technical monitor was Michael Nuckols, ATZB-PWN-P.

The work was performed by the Natural Resource Assessment and Management Division (LL-N) of the Land Management Laboratory (LL), U.S. Army Construction Engineering Research Laboratories (USACERL). The USACERL principal investigator was Dr. Diane K. Mann. At the time of this study, Marilyn K. Weiss and Scott Twait were graduate students at the University of Illinois, Champaign-Urbana. Some data from this report were developed as part of Masters theses research for Marilyn K. Weiss's *A Hydrogeologic Assessment of a Proposed Landfarm Site at Fort Benning, Georgia*, and Scott Twait's *Subsurface Modeling of Fort Benning Landfarm Site*. Dr. David J. Tazik is Acting Chief, CECER-LL-N; Dr. William D. Severinghaus is Operations Chief, CECER-LL; and William D. Goran, CECER-LL, is the responsible Technical Director. The USACERL technical editor was William J. Wolfe, Technical Resources.

COL James A. Walter is Commander and Dr. Michael J. O'Connor is Director of USACERL.

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1 Introduction

Background

Fort Benning is located approximately 12.87 km (8 mi) south of the city of Columbus in the west-central part of Georgia with part of the reservation located across the Chattahoochee River which forms the Georgia-Alabama border. The military reservation is comprised of 181,835 acres; 169,679 acres are in Georgia in the counties of Chattahoochee and Muscogee and 12,156 acres are in Alabama in Russell county. Located on the northern edge of the Atlantic Coastal Plain, the predominantly rolling pine-covered surfaces are highest in the east, up 740 ft above sea level, and lowest in the southwest, about 190 ft above sea level along the Chattahoochee River.

Fort Benning has been exploring the feasibility of a landfarm as a proactive technology to assure preparedness for spills and leaks that contaminate soil with POL. Preliminary studies led to the selection of a prospective landfarm site. The proposed landfarm site, previously used as an Apari heliport, is southwest of the intersection of Jamestown Road and Eighth Division Road in the Harps Creek local drainage system (Figure 1). Further, more detailed studies and hydrogeological modeling of the proposed landfarm site were required.

Objectives

This objective of this research was to verify the selected site's positive features for treating POL contaminated soil and to identify and explore weaknesses that would have to be ameliorated through design.

Approach

1. A hydrologic assessment of the Fort Benning site was done.
2. A groundwater flow assessment was done via 2-dimensional modeling software.

3. Subsurface sampling was done to determine soil composition and characteristics by:
   a. taking seven soil borings
   b. converting four of the borings into monitoring wells.
4. The flow of water and contaminates through saturated and unsaturated soil layers was modeled via 2-dimensional computer modeling program.
5. Results of the modeling were analyzed and conclusions were drawn regarding the suitability of the Fort Benning site for a landfarm application.

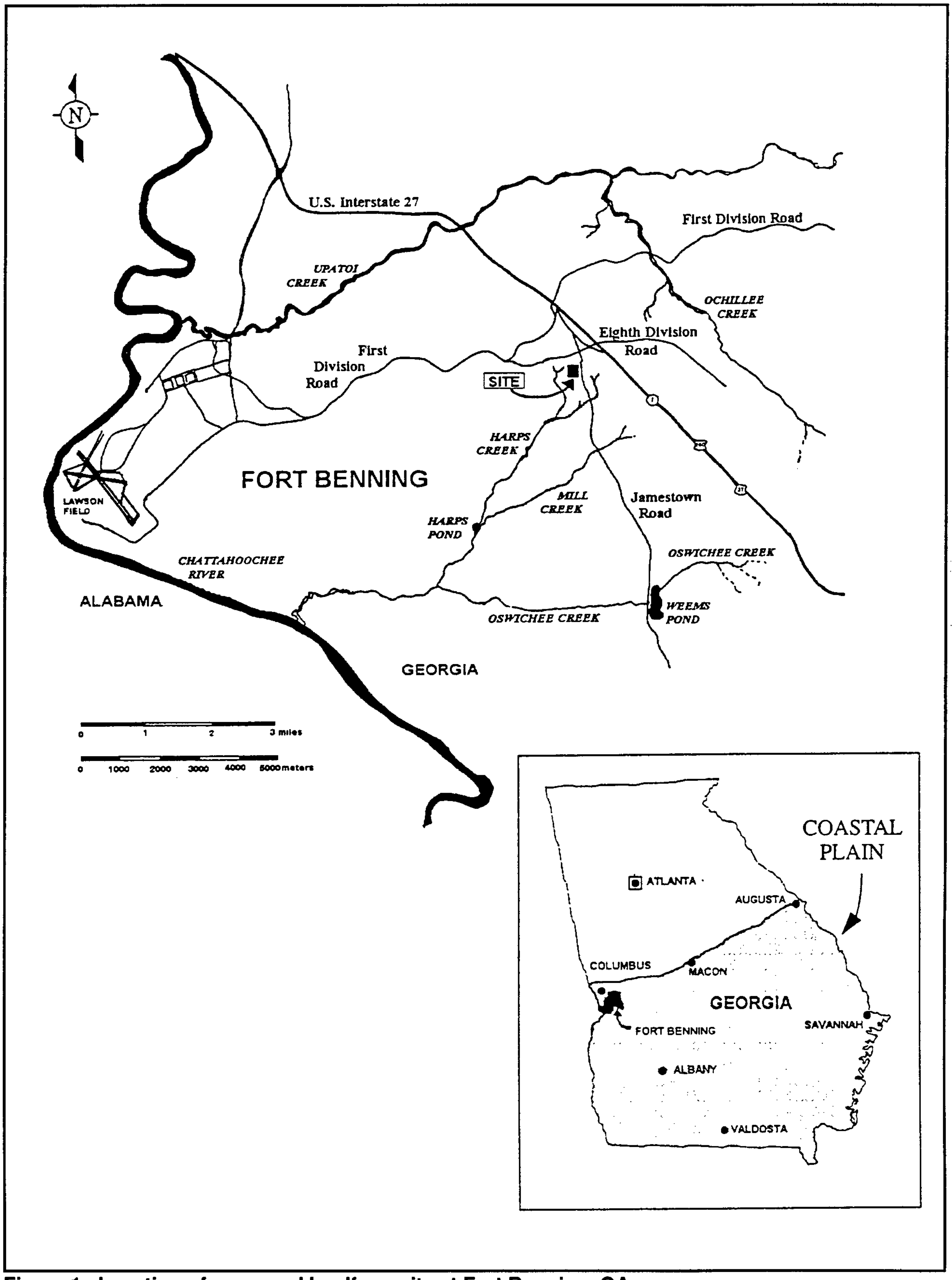


Figure 1. Location of proposed landfarm site at Fort Benning, GA.

2 Master Plan

The proposed Fort Benning landfarm is within the boundaries of the military installation and is the property of the U.S. government (Figure 1). Currently used for storage of disabled military tanks, the former heliport is relatively flat, sparsely vegetated, surrounded by asphalt roads, and partially covered by steel lattice gridwork (landing mat).

Site Plan

The study included the area that could be incorporated into a landfarm approximately 20 acres, totally enclosed by levees (Figure 2). Of the 20 acres, approximately 6 acres in the northwest corner are designed for impounded runoff. The retention pond is designed to be 5-ft deep and sized to hold the runoff from a maximum 24-hour storm. Useable landfarm is divided into five separate treatment areas, arranged in order so that furrows would run perpendicular to the predominant slope (at a 2 to 3 percent grade). Each treatment area is about 300 X 150 ft (approximately 1 acre). A 300 X 30-ft grassy buffer strip between each treatment area is part of the design to further inhibit runoff. Total treatment area of 5 acres has an assimilative capacity of 119,790 lb (nearly 60 tons) per year for oily wastes at a 1 percent loading rate. The estimated yearly average of oily contaminated soil needing treatment is 50 tons. Some sludge will probably be mixed in with the oily soil to enhance the biodegradation process. The yearly estimated average of sludge generated at Fort Benning is 1,260,000 gal, but the amount incorporated into landfarm would depend on the amount of soil being treated and the proportion required for ideal treatment. Supporting calculations may be found in Appendix A. Minor amounts of treated sewage sludge would also be applied.

The proposed landfarm site is within a significant recharge area (Davis et al. 1992) and a synthetic liner would be used that matches the impermability of 3 ft of smectite clay as a barrier, even though the DRASTIC index (141-181) (Allen et al. 1987; Trent 1992) for the landfarm site is within the zone of average susceptibility to groundwater pollutants. The State currently regulates only areas of greater susceptibility.

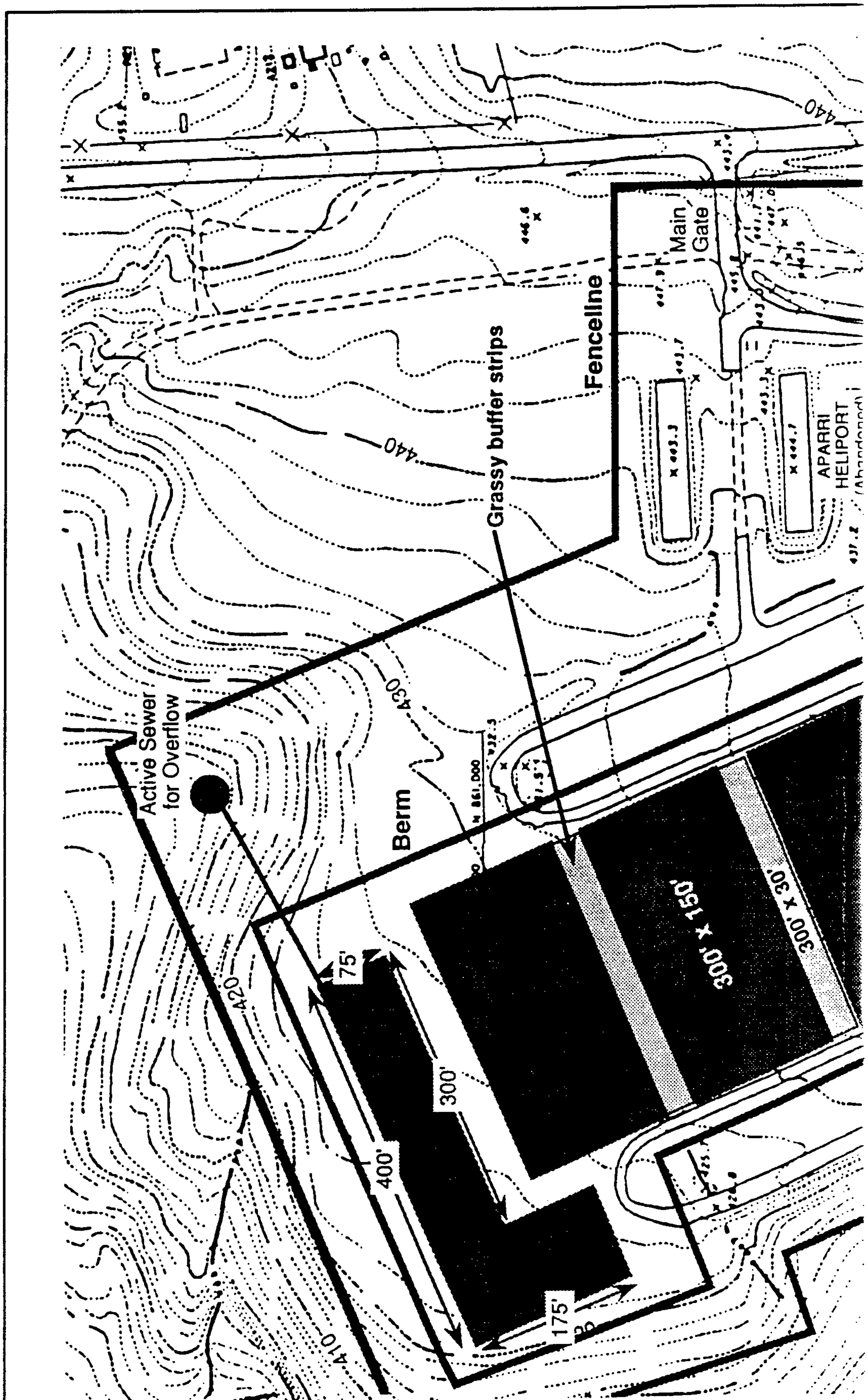
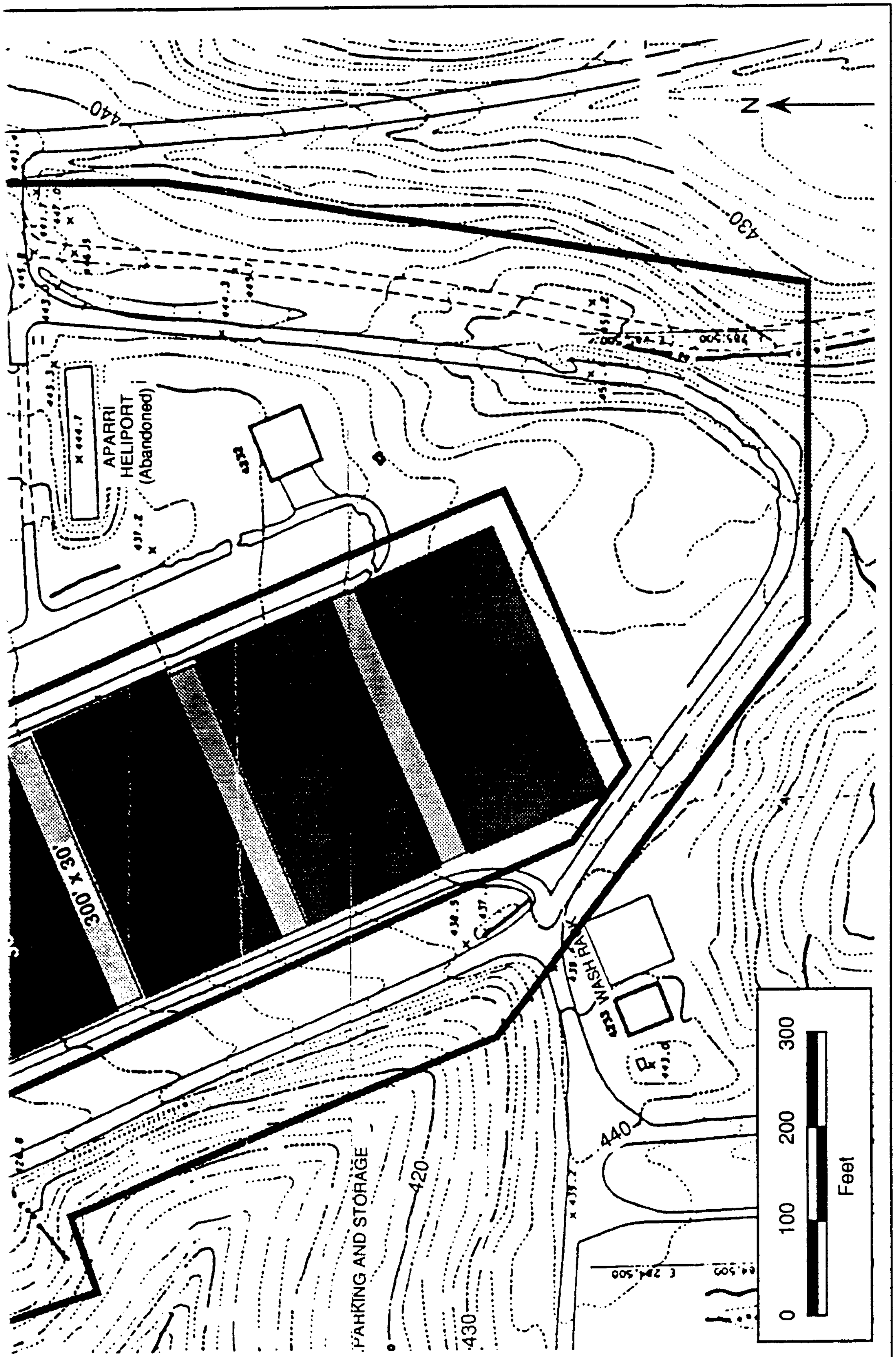


Figure 2. Proposed landfarm site.


N
440
430
APARRI
HELIPORT
(Abandoned)
300' x 30'
PARKING AND STORAGE
420
430
440
0
100
200
300
Feet

Site Research Data

Aquifers

The RASA study (Renken et al. 1989; Miller and Renken 1988) divided the Coastal Plain into four major regional aquifer systems: Northern Atlantic Coastal Plain, Southeastern Coastal Plain, Floridian, and Gulf Coastal Plain aquifer systems. The landfarm site is near the northern edge of the Southeastern Coastal Plain aquifer system. This system stretches through parts of Mississippi, Alabama, Georgia, South Carolina, and the northern part of Florida. The RASA report analyzed the Coastal Plain formations from the perspective of hydraulically interconnected strata or hydrostratigraphic units rather than according to classical geological stratigraphic units due to their regional extent and poor correspondence with physical boundaries of rock-stratigraphic and time-stratigraphic units. The Southeastern Coastal Plain aquifer system was subdivided into seven regional hydrogeologic units; four aquifer units identified as A1 through A4 are separated by three confining units, C1 through C3 (Appendix B).

Units A3, C3, and A4 are most likely to exist at the study area. The A3 regional aquifer extends as a continuous unit from North Carolina to central Alabama with the updip limit of the aquifer occurring at or near the Fall Line. It includes Blufftown Sands through the upper part of the Eutaw Formation. The upper surface of the aquifer slopes gently toward the coast at a gradient of 2.84 to 3.79 m/km (15 to 20 ft/mi). Hydraulic conductivity of the water-bearing zones within the A3 aquifer diminishes at depth as sandy strata of this unit grade into calcareous shale and chalk. Permeable parts of the aquifer thin greatly seaward; however, in southeast Georgia, it grades into permeable limestone that is part of the Floridian aquifer system. In western Georgia, the aquifer consists of shallow marine to nonmarine, feldspathic and locally glauconitic quartz sand and gravel that is, in places, interbedded with ferruginous, kaolinitic, and carbonaceous clay.

The C3 confining unit consists of oxidized, nonmarine, sandy and silty clay in shallow-updip areas of South Carolina and northeastern Georgia, but in other areas grades into marginal marine and marine calcareous clay, shale, mudstone, marl, and chalk. In much of Georgia, the poorly permeable beds that form the unit are considered equivalent to the clays of the Eutaw Formation or lower part of Blufftown Formation. The unit consists of chalky, micaceous, calcareous

carbonaceous clay that is silty and sandy locally. Minor amounts of glauconite, phosphate, and chlorite are present locally.

The A4 aquifer unit regionally is the most extensive clastic aquifer of the southeastern United States Coastal Plain and extends from South Carolina through Mississippi. Strata of this unit are equivalent to Eutaw and upper part of Tuscaloosa Formation. The aquifer is comprised of sparsely fossiliferous greenish gray to yellowish brown, fine to coarse grained, glauconitic calcareous sand that is interbedded with gray micaceous shale. Minor constituents include volcanic ash (bentonite), siderite, pyrite, and lignite. The upper surface of A4 aquifer slopes gently seaward at a gradient of 2.84 to 5.68 m/km (15 to 30 ft/mi) in Georgia, northern Florida, South Carolina, and adjacent counties of North Carolina, but slopes more steeply in Alabama and Mississippi. Similar to A3, the updip limit marks the inner margin of Coastal Plain sediments.

Neither previous hydrogeologic studies at Fort Benning nor this field study encountered the C3 confining unit; instead, base studies show groundwater to be hydraulically connected throughout Upper Cretaceous deposits reaching a total thickness of about 28.5 m (750 ft). Water table conditions exist at Fort Benning, but farther south, groundwater is confined by poorly permeable units. Water from Cretaceous aquifers is generally soft, and contains small quantities of dissolved solids. Water quality varies somewhat throughout various formations with best quality water in Tuscaloosa strata. Silica, calcium, and sulfate content is greater in Eutaw and Blufftown strata. Iron also occurs at greater concentrations in these formations and pH is lower (about 5 as opposed to 7) in the Tuscaloosa Formation. Wells finished in the Blufftown and Eutaw Formation have yielded up to 700 gpm (2.65 m^3/min). Tuscaloosa Formation wells have yields up to 400 gpm (1.5 m^3/min) (Meckelnburg 1993).

Fort Benning obtains most of its water supply from a surface intake structure in the Upatoi River upgradient from the proposed landfarm site. Additionally, the base operates three groundwater wells that serve a population of 1 to 100 persons and range in depth from 61.0 to 164.6 m (200 to 540 ft), probably tapping sands of the A4 aquifer unit. Locations of these groundwater sources also are upgradient from Harps Creek and the landfarm site. No known regional water sources or water intake structures exist within 24.1 km (15 mi) downgradient of the site (Figure 3).

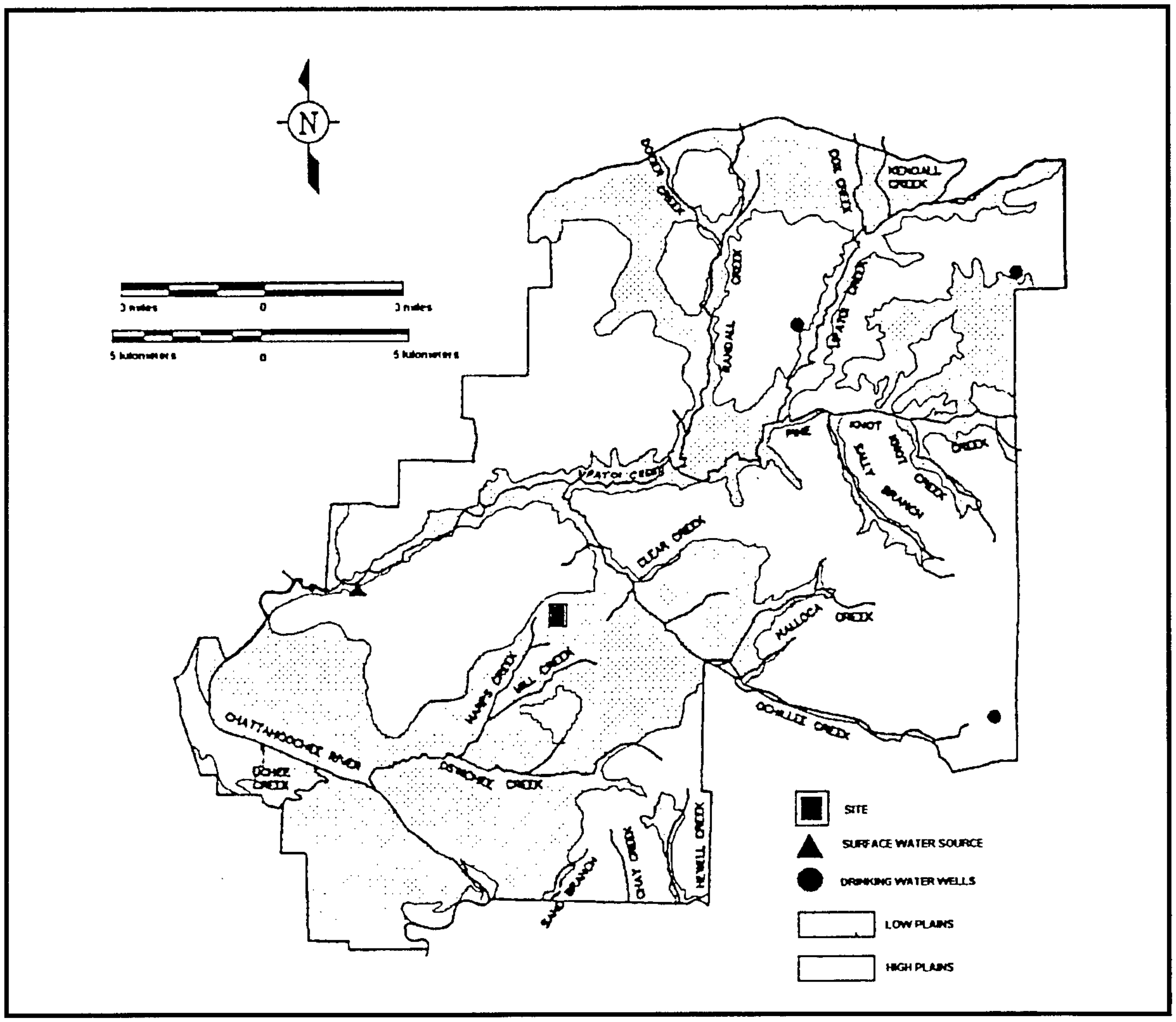


Figure 3. Location of site in relation to surface water and potable water sources.

Climate

Fort Benning has a humid, subtropical climate characterized by long hot summers and mild winters.

Drainage

The proposed landfarm site is on a local topographic high that is part of a broad upland ridge with a gentle zero to 5 percent slope and characterized as part of the low plains (Terrain Analysis Center 1976). Intermittent streams surround the site on three sides and are deeply incised with slopes that range from 10 to over 45 percent. Elevation across the site slopes from 139 m (456 ft) to 128 m (420 ft) above MSL. The site is in the headwaters of Harps Creek, approximately 20 m (65 ft) to 35 m (115 ft) above the nearest intermittent

stream bed. The intermittent streams become permanent downstream, where stream beds broaden out and become more swamp-like, especially during periods of heavy rainfall. Ephemeral streams at the top of the watershed direct run-off primarily to the southwest becoming permanent and combining with Mill Creek at Harps Pond. Combined drainage of Harps and Mill Creeks flows into Oswichee Creek and subsequently drains into the Chattahoochee River, which flows southeast through the western part of Fort Benning. Watershed for Harps Creek up to Harps Pond encompasses approximately 11.93 km^2 (4.59 sq mi) (Figure 3). Surface water eventually empties into the Gulf of Mexico.

Shallow groundwater at Fort Benning normally flows in the same direction as surface water (USATHAMA 1992). Northeast of the site lies a regional groundwater divide. The divide is mostly coincident to U.S. Interstate 27, which runs northwest to southeast. Running parallel to the highway is Ochillee creek to the east and a portion of the Chattahoochee River to the west. Waters that fall east of the highway drain into Ochillee Creek and waters that fall west of the highway drain south to Chattahoochee River through such creeks as McMurrin Branch, Harps Creek, Mill Creek, and Oswichee Creek.

U.S. Geological Survey records show that of the average 127 cm (50 in.) of rainfall received by the State of Georgia, 18 percent becomes runoff, 70 percent is lost to evaporation, and only 12 percent has the potential of entering into aquifer systems (Kundell 1978). Large evapo-transpiration losses are the primary factor influencing seasonal water table fluctuations in unconfined groundwater. Shallow groundwater levels within the root zone vary annually, rising when plants are dormant and falling during the growing season. However, water level fluctuations in deep unconfined aquifers are the result of seasonal recharge patterns and water withdrawal.

Environmental Characteristics

There are no known archeological sites, historical sites, designated wildlife management areas, habitat for endangered species, recreational areas, swamps, marshes, or other sensitive ecological areas within 1000 ft of the proposed landfarm site. Consequently, no protective measures for such occurrences are necessary.

Temperature

Climatological data has been recorded at Lawson Army Airfield 7 miles west of the landfarm site (Figure 1). The annual mean temperature is approximately 18.7 °C (64.9 °F). The maximum and minimum daily means for each month fluctuate with the season (Appendix C). During July, mean maximum and mean minimum temperatures are 32.8 °C (91.0 °F) and 21.3 °C (71.1 °F), respectively. Whereas for January, the mean maximum temperature is 15 °C (59 °F) and mean minimum is about 2.2 °C (36 °F) (USATHAMA 1992).

Humidity

The relative humidity ranges from a mean of 49 percent in April and May to a mean of 59 percent in January and July; the average relative humidity in midafternoon is 54 percent (Appendix C).

Rainfall

The annual average rainfall at Fort Benning is approximately 124 cm/yr (48.8 in/yr). Yearly totals for years 1960 through 1993 range from 36.04 to 67.50 in. (Appendix D). Rainfall distribution has major peaks in March and July with a secondary peak during winter months of November and December (Appendix E). Periods of least precipitation are usually during May or June and again in October. The maximum Fort Benning yearly precipitation within the last 30 years was 171.5 cm (67.50 in) and 163.5 cm (64.37 in) in 1979 and 1964, respectively. The U.S. Soil Conservation Service (SCS) recorded the heaviest 1-day rainfall for the period of 1951 to 1977 at 13.5 cm (5.32 in) on 3 August 1977 in Columbus, GA (Johnson 1983). Monthly summaries of rainfall intensity data for Fort Benning are presented in Appendix F.

Water Quality

Water quality analyses were performed (Appendix G) to characterize the groundwater present at the site. Results of these analyses exhibited small levels of specific conductance (Appendix H). Due to the direct relationship of specific conductance and dissolved solids concentrations (Hem 1985), small specific conductance indicates a diminished level of dissolved solids. Samples ranged in pH from 3.5 to almost 7. Chemical analysis of nearby groundwater (Appendix I), similarly found levels of small specific conductance and generally acidic water with pH values that ranged from 3.5 to 4.5 (Meckelnburg 1993). The acidic nature of the water probably is a natural occurrence related to acidic

soil and sediments of the Coastal Plain. Small levels of dissolved solids are typical of waters with a brief residence time in the ground. The site is within a natural recharge area, near a topographic high of the water watershed and only 762 to 914.4 m (2500 to 3000 ft) from a regional groundwater divide. Porosity and conductivity of the site's subsurface material allow precipitation to infiltrate quickly to the groundwater zone. Thus, the main source of groundwater in the study area is infiltrating rainwater and is consistent with the finding of small concentrations of dissolved solids.

A marked similarity is found in fingerprint diagrams (Brassington 1988) comparing samples from MW-1 and surface water (Figure 4). Though not identical, the differences are probably due to the different histories of subsurface interactions encountered by the two waters. Surface water is a product of groundwater baseflow mixed with direct run-off of rainwater that has no residence time in the groundwater reservoir and only short contact with soil or vegetation. This causes surface samples from flowing streams to have a similar composition as rainwater with little dissolved solids. The small dissolved solids content of surface water is to be expected when groundwater also has little dissolved solids content. Lack of any one dominant anion or group of anions indicates a strong connection between groundwater and surface water at the site. In addition, all water samples, except for BH-4, had similar concentration of chloride, a conservative ion that moves through both soil and water with minimal retardation.

Scatter diagrams that plot various ion concentrations versus total dissolved solids, illustrate that waters of both subsurface and surface are related strongly to rainwater, except for samples BH-2 and BH-4, which exhibit some form of contamination. Loosely clumped together on the diagrams are surface water samples MW-1 and BH-3 (Appendix J).

Winds

Prevailing winds are from the north in the spring shifting to southwesterly in midsummer. Wind speeds are relatively small throughout the year, averaging 7.08 km/h (4.4 mi/h). Greatest average wind speeds recorded are in the spring at 12.87 km/h (8 mi/h) (Johnson 1983).

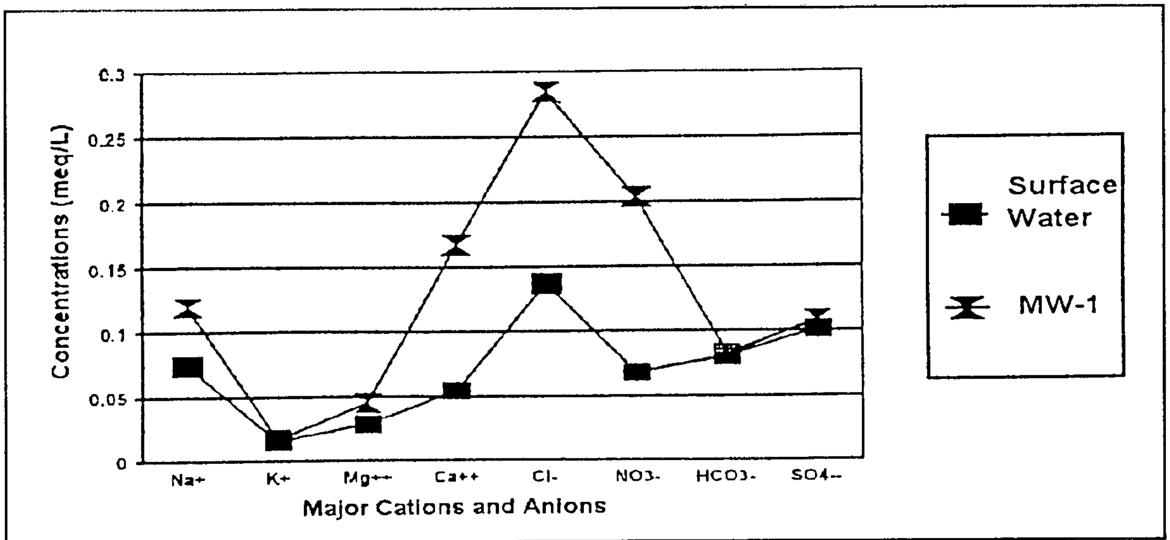


Figure 4. Fingerprint diagram comparing surface water sample and MW-1 sample.

Geological Characteristics of Coastal Plain

In Georgia, the Coastal Plain province is characterized by a series of unconsolidated and poorly consolidated interbedded gravels, sands, and clays that lie unconformably over crystalline rocks of the Piedmont province. The Coastal Plain is bounded on the north by the Fall Line where rocks of the Piedmont province cropout and form a more resistant material than the poorly inundated Coastal Plain sediments. Composition of the Piedmont is a complex mass of Precambrian igneous and metamorphic rocks with a deeply weathered and eroded surface. Fort Benning is entirely within the Coastal Plain with the northern edge of the installation bordering the Fall Line. Proposed landfarm site lies approximately 16.09 km (10 mi) south of the Fall Line.

Coastal Plain sediments at the site are entirely Late Cretaceous age. Four formations are defined from study of outcrops in the Fort Benning area. Traditional reference in chronological order of oldest to youngest is: Tuscaloosa Formation, Eutaw Formation, Blufftown Formation, and Cusseta Sand (Appendix K). These surface units have been mapped extensively throughout the Fort Benning/Columbus area and along Chattahoochee River (Cooke 1943; Eargle, 1955; Herrick and Vorhis 1963; Marsalis and Friddell 1975; Frazier 1977; Reinhardt and Gibson 1981). However, the Eutaw Formation, Blufftown Formation, and Cusseta Sand units tend to lose their identities in the subsurface. Different authors have constructed geologic maps that place the site within different formations, for example, Eutaw Formation (Cooke 1943) and

Blufftown Formation (Eargle 1955). The most recent study of the southeastern Coastal Plain was part of the U.S. Geological Survey's Regional Aquifer-System Analysis (RASA) program, whose objectives included analysis of major groundwater systems of the United States on a regional scale. Renken et al. (1989) (Appendix B) have correlated the Coastal Plain stratigraphic units for much of the southeast from Mississippi to South Carolina.

Cretaceous sediments of the Georgian Coastal Plain consist of lithologies indicative of erosion products transported from uplifted rocks to the northwest. Following transportation, the sediments were deposited in a deltaic environment where shifting river channels, lakes, and swamps prevailed. Due to cyclical advance and retreat of the sea during the Late Cretaceous Period, depositional environments range from largely continental (fluvio-deltaic) to predominantly marine, varying laterally as well as vertically within the stratigraphic record. Along the Chattahoochee River, Blufftown, and Eutaw Formations consist of marine fossiliferous sand and calcareous silty clay, but grade into nonmarine sediments to the east toward the Ocmulgee River. Cretaceous sediments become more representative of an offshore marine depositional environment as they dip southeastward beneath younger formations.

The area of Cretaceous rocks increases in width towards the west and Cretaceous rocks thicken downdip to the southeast. In western Georgia, the surface strike of crystalline rocks on which basal Coastal Plain rocks lie is N. 77 degrees E. and their dip is approximately 14.78 m/km (78 ft per mile) in the Chattahoochee Valley with a strike of about N. 85 degrees E. Due to the fact that Blufftown and Eutaw beds become similar, Eargle (1955) was unable to trace accurately their contact, but where it was traceable, the strike was about N. 75 degrees E. Top of the Blufftown Formation strike was approximately N. 67 degrees E., dipping southeastward at a little more than 5.68 m/km (30 ft per mi).

Groundwater

Water table levels of the area generally are subdued replicas of land surface topography. They range from 28.04 m (92 ft) below land surface of the landfarm site to at or near surface level in low swampy areas downgradient. Precipitation not lost through run-off readily infiltrates permeable subsurface materials and moves vertically to the saturated zone and then laterally, from areas of high elevation to areas of low elevation. Lateral movement is interrupted locally by swamps, creeks, and intermittent streams into which groundwater discharges. Additional water is lost by downward leakage to lower aquifer systems and by

typical of unconfined conditions has vertical no flow boundaries beneath valleys and ridges (Figure 5). Groundwater flow at Fort Benning appears to fit this idealized model. Due to the connection of groundwater and surface water, the most easily recognizable groundwater divides for the area are boundaries of the watershed.

The subsurface is assumed homogenous and isotropic (Figure 5) where upland areas serve as recharge areas and valleys are discharge areas creating a uniform single local flow system. In reality, an infinite variety of subsurface and surface variations and anisotropic conditions exist creating regional systems of groundwater flow. However, as Freeze and Cherry (1979) noted, "... where there is pronounced local relief, only local systems develop." For purposes of the landfarm study, the watershed of Harps Creek prior to its combination with other streams was defined as the local groundwater flow system. Larger groundwater flow systems are defined as groundwater that traveled out of the watershed and discharged into larger bodies of water.

Because of the pronounced topography relief of the area, topography may be considered the major controlling aspect of groundwater flow; thus the majority of recharge of the watershed should discharge into Harps Creek. In addition, even though subsurface stratigraphy shows a great variability of sediments, ranging from permeable, well sorted medium-grained sands to clayey sands and lenses of clay, no perched water table or poorly permeable continuous unit of any significant thickness was encountered. Therefore, the study area, at a first approximation can be considered homogeneous and isotropic for studying groundwater flow.

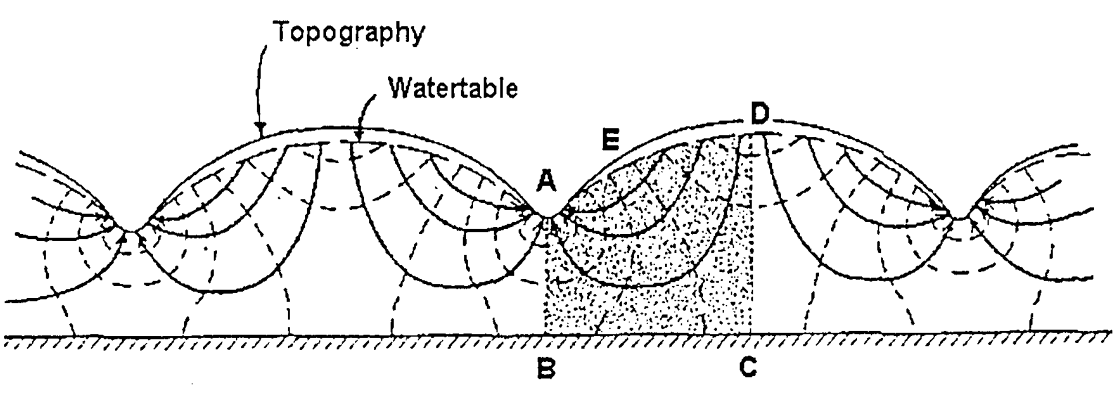


Figure 5. Idealized cross-section of groundwater flow patterns (after Freeze and Sherry 1979, modified from Hubert, "The Theory of Groundwater Motion, *Journal of Geology*, vol 48 [1940], pp 785-944).

Soil

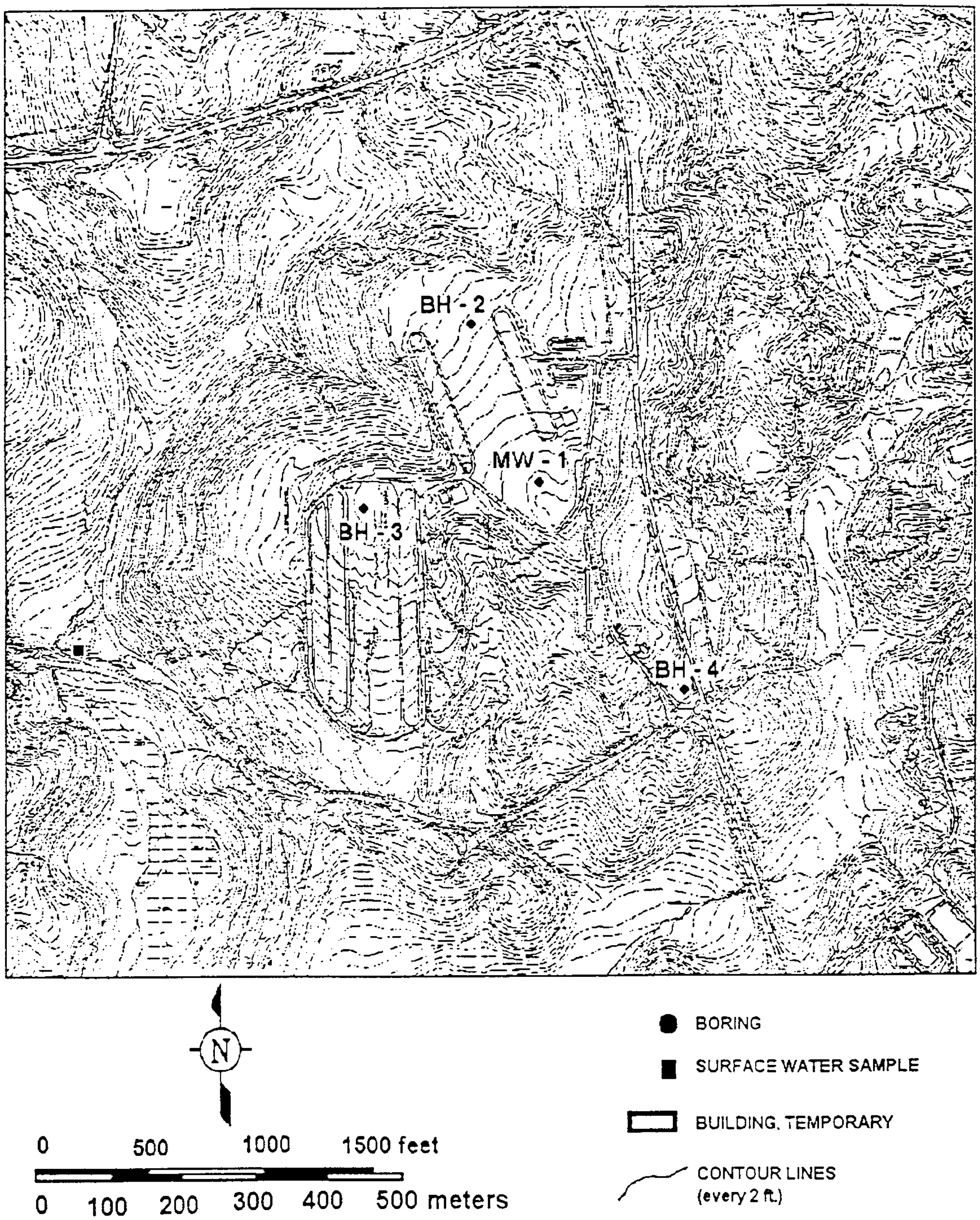
No soil types have been delineated by the SCS for the Harps Creek watershed; however, they have been defined for the Oswichee Creek watershed to the south of Harps Creek. Using similar topography as a guide, the following soils are typical of the proposed landfarm site: Cowarts, Ailey, Nankin and Troup. These soils (Table 1) range from moderately to well drained soils, with Unified Soil Classifications of sandy clay loam, sand loam, and sandy clay. They are generally less than 50 percent clay, more than 50 percent sand, and acidic. All but Nankin soils are siliceous.

Stratigraphy

Deep wells drilled near the site have found that combined thickness of Upper Cretaceous units is approximately 228.6 m (750 ft) with the Blufftown and Eutaw Formations comprising the upper 121.92 m (400 ft) (Meckelnburg; Marsalis and Friddell 1975). Four borings were drilled using a hollow stem auger. The location of each boring (Figure 6) was chosen to provide an understanding of local groundwater flow patterns. All were drilled to a depth of approximately 3.05 m (10 ft) below the water table and ranged in depth from 19.81 to 31.09 m (65 to 102 ft). The first boring (MW-1) is at the visual topographic high of the site and was completed as a 2-in. piezometer by installing a PVC casing and screen, and a clay seal. Aquifer characteristics were all determined at MW-1. Remaining three borings were numbered BH-2, BH-3, BH-4 with the later two located outside the landfarm site (Appendix L). Split spoon samples were taken at 5-foot intervals in all borings and geologically described (Appendix M).

Grain size analysis was performed on selected representative samples (Appendix N). Sediments were classified using the Unified Soil Classification System (USCS) (ASTM 1950) as SC, clayey sands, sand-clay mixtures; and SP, poorly graded sands, gravely sands, little or no fines. Samples from the top of BH-3 and the bottom of BH-4 were the only samples classified as CL, inorganic clays of poor to medium plasticity, gravely clays, sandy clays, silty clays, and lean clays.

Correlations and exact formation identifications from the site borings are difficult due to the lack of continuous sampling and variability of sediments within the formations. Sediments vary from bright white to tones of red and yellow with mottling of browns, purples, and greenish gray clays.



(Source: U.S. ARMY Corps of Engineers, Savannah District)

Figure 6. Topographic map of proposed landfarm region and location of borings.

Table 1. Soils typical of the site (after Frost, in print).

Soil Series	Texture	Clay %	Permeability* (in/hr)	pH	CEC (meq/100g)	Organic Matter (%)	Hydrologic Group
Ailey	Sandy Clay Loam	3 – 35%	0.06 – 20	4.5 to 6.5	0.3 – 2.0	0.5 – 1	B
Troup	Sandy Loam or Sandy Clay Loam	1 – 35%	0.6 – 20	4.5 to 6.5	–	0.5 – 1	A
Cowarts	Sandy Loam or Sandy Clay Loam	3 – 40%	0.06 – 6.0	4.5 to 6.5	1 – 10	0 – 3	C
Nankin	Sandy Loam, Sandy Clay, and Sandy Clay Loam	5 – 50	0.2 – 6.0	4.5 to 6.5	1.0 – 5.5	0.5 – 1	C

*Permeability refers to ability of a soil to transmit water or air. Estimates indicate rate of downward movement of water when soil is saturated and are based on soil characteristics observed in the field, particularly structure, porosity, and texture (Johnson 1983).

Many samples were so commonly mottled and variegated that an accurate description with the Geological Society of America Rock-Color Chart (1963) was difficult. In general (Figure 7), collected sediments are: (1) sand to clayey sand with medium- to fine-grained, subangular to subrounded, quartz, (2) micaceous, and (3) containing ferruginous darker-colored clay aggregates or nodules in addition to several small lenses of noncontinuous clay units. Lignitized plant species in a clayey sand bed at the bottom of first boring were the only fossils found.

Sediments Beneath the Soil Horizons

Nearby hydrogeologic investigations analyzed samples from 0.91 to 14.02 m (3 to 46 ft) below the surface for CEC and moisture content (Meckelnburg 1993). CEC was found to range from 1.1meq/100g between a depth of 9.45 and 12.19 m (31 and 40 ft) to 14 meq/100 at about 9.14 m (30 ft) with and average of 5.5 meq/100 g. The cutoff between large and small CEC is 10 meq/100 g (Buol et al. 1973) indicating that most material in the unsaturated zone has a limited capacity to attenuate any potential contaminant by cation exchange. However, continuous borings may find discontinuous layers of finer materials with greater exchange capacities for contaminant retention. Moisture content for these nearby sediments typically was small, with less than 10 percent moisture content due to the well drained nature of the sediments.

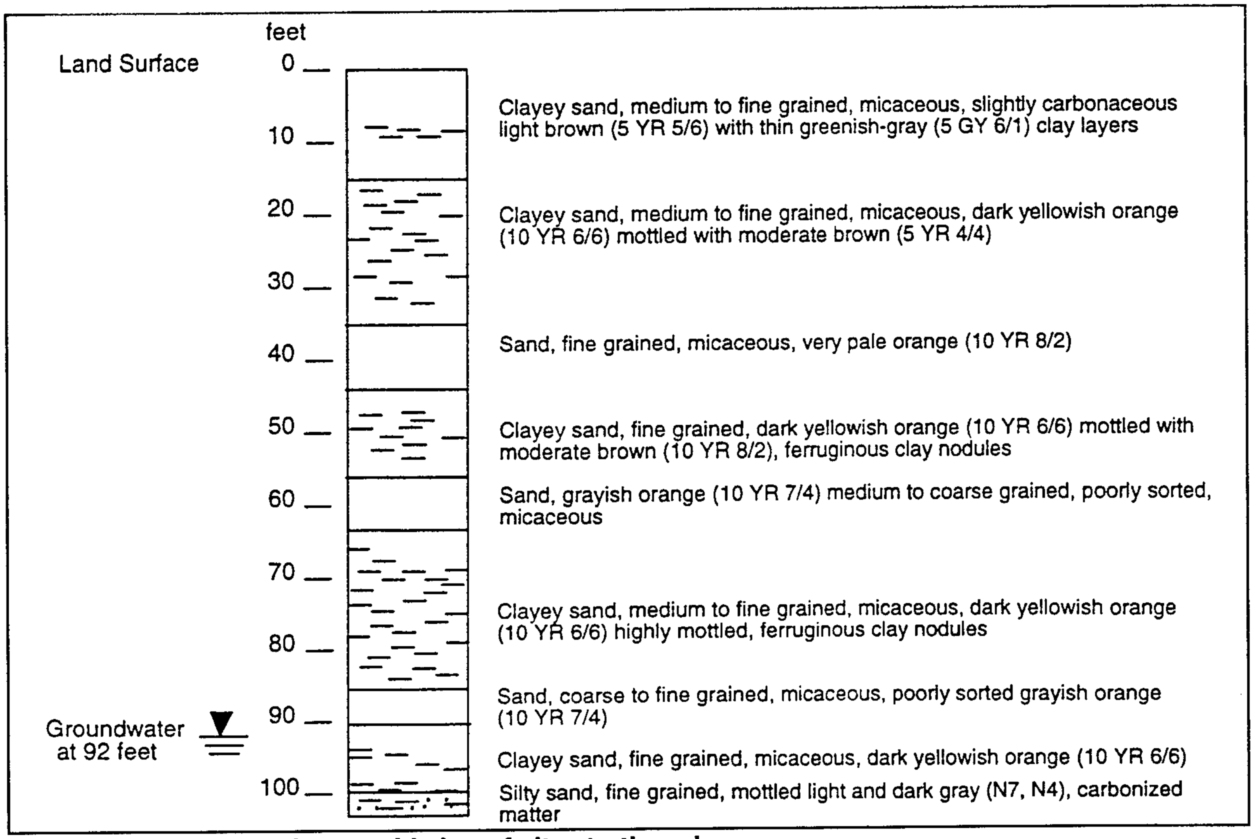


Figure 7. Representative graphic log of site stratigraphy.

3 Site Modeling

Field Data

Groundwater levels in the monitoring well and borings ranged from 28.0 to 17.7 m (92 to 58 ft). Aquifer characteristics of MW-1 were estimated through lab analyses and slug tests. In addition, porosity and vertical hydraulic conductivity were determined in the lab from a relatively undisturbed (Shelby Tube) sample collected from bottom of MW-1. Slug tests were used to determine hydraulic conductivity and involved lowering a 3-ft by 1-in. galvanized steel slug into the well, which displaced approximately 9 in. (0.75 ft) of water. The slug was positioned below the original well water level and the time and recovery of the water levels were recorded with an In Situ "Hemit" R data recorded. Once the well water equilibrated, the slug was removed from the well, and again the time and recovery of the water levels were recorded. The computer program, AQUITEST, and the Bouwer and Rice Method (1976) were used to calculate hydraulic values (Appendix O).

Field values for hydraulic conductivity ranged from 6.60 x 10-4 to 2.91 x 10-5 cm/sec (1.30 x 10-3 to 5.72 x 10-5 ft/min). Vertical hydraulic conductivity of 1.8 x 10-4 cm/sec (3.54 x 10-4 ft/min) was determined from laboratory analysis of an undisturbed MW-1 sample. Other hydrogeologic investigations (Meckelnburg 1993; Fox 1993) within a mile radius of the site produced hydraulic conductivity values of 3.55 x 10-4 to 4.88 x 10-3 cm/sec (6.99 x 10-4 to 9.6 x 10-3 ft/min). Taking into account site variability and probable slug test error, a conductivity value of 1.4 x 10-4 ft/min was deemed reasonable. Additionally, the "undisturbed" MW-1 sample produced a laboratory porosity of 47 percent. However, in-situ soil porosity probably is much less because samples may not have been packed as tightly as when in the subsurface. Therefore, based on published porosity values for compacted sediments, a porosity of 30 percent was selected for the purpose of modeling.

Groundwater Flow

Based on the assumption of a single flow system for the study region, water table contours were determined from hydraulic heads measured in three borings, BH-2, BH-3, and BH-4. Provided that homogeneous and isotropic conditions exist, groundwater flow is perpendicular to these water table contours (Figure 8). Groundwater velocity in the saturated zone of the site along the direction of flow can be computed from the following modification of Darcy's Law (USEPA 1989):

$$v = KI / n \qquad \textbf{Eq 1}$$

where:

v = groundwater flow velocity
K = hydraulic conductivity
I = hydraulic gradient
n = effective porosity.

The resultant calculation is:

$$\left[\left(1.4 \times 10^{-4}\right)\left(\frac{355.5 - 350.8}{410.2}\right)\right] / (0.3) = 5.7 \times 10^{-6}\, ft / day\, (0.002\, m / day)$$

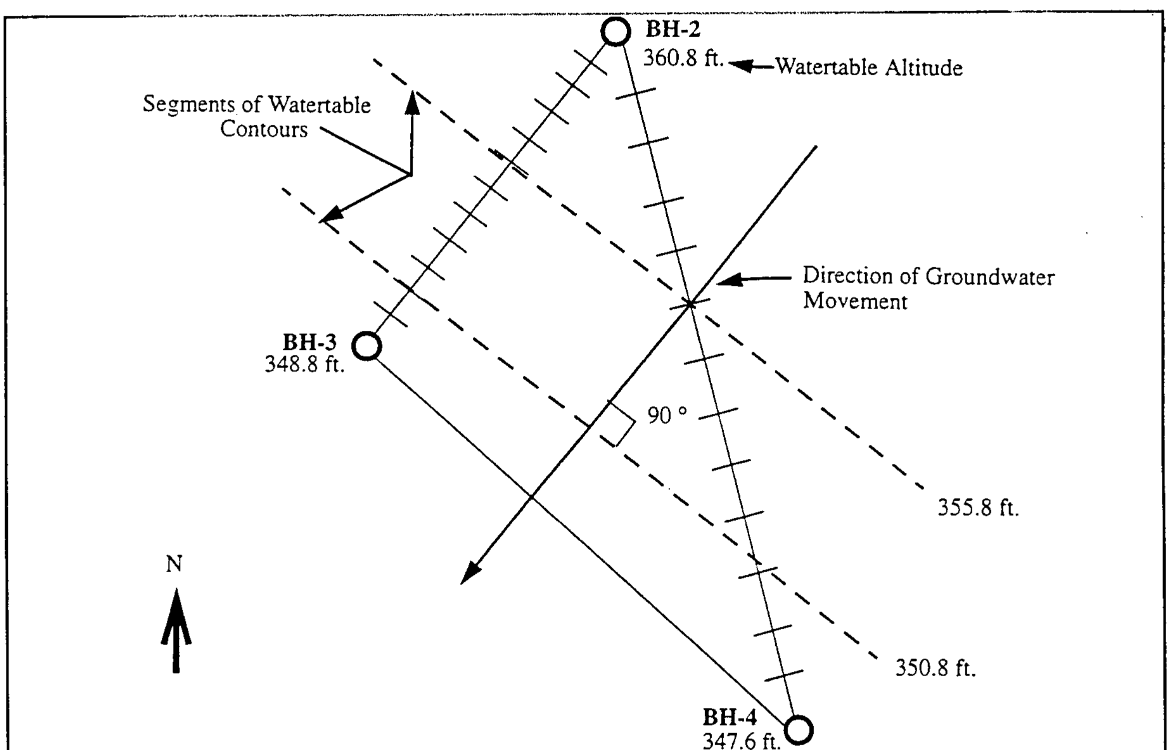


Figure 8. Direction of groundwater flow for proposed landfarm region.

Numeric Groundwater Model

The two-dimensional computer program used to stimulate groundwater flow of the site was a PC-modified version of MODFLOW, called GRAPHIC GROUNDWATER, version 1.1 (Esling and Larson 1993). Chosen because of its enhanced data input and display features, it is based on a well-documented finite difference groundwater flow modeling program.

Boundaries of the watershed were estimated from Fort Benning GIS files in combination with topographic maps. The area was discretely divided into blocks that varied from 304.8 by 304.8 m (1000 by 1000 ft) at the southern edges of the watershed to 38.1 by 38.1 m (125 X 125 ft) over the landfarm site. This nonuniform grid was used to decrease computation time for each simulation; in addition, conditions farther from site will have less impact on flow at the site. The number of cells totaled 1333 (31 rows by 43 columns) (Figure 9). Vertically, cells encompassed the ground surface down to the top of the first confining layer including the water table. Elevations of the ground surface were derived from the Fort Benning Reservation Map revised in April 1962 (Corps of Engineers). The bottom depth of the unconfined aquifer was arbitrarily set at zero ft above MSL because the top of the confining layer is unknown at the site; however, nearby geological studies place it at approximately 400 ft. This is sufficient depth to have no impact on the shallow groundwater flow. Horizontal hydraulic conductivity was assumed to be greater than vertical conductivity and the model was calibrated to find the best value for horizontal conductivity.

Recharge rates were estimated from the 30-year average rainfall for Fort Benning of 123.95 cm/yr (48.8 in/yr) and the SCS method for abstractions (Chow et al. 1988). An annual rainfall of 123.95 cm (48.8 in.), normal antecedent moisture climate, and a soil hydrologic group of B was used to calculate run-off. Run-off was computed at 113.79 cm/yr (44.80 in/yr) with an infiltration rate of 10.16 cm/yr (4.0 in/yr) (Appendix P) equaling a net recharge for the study region of 1.83 x 10-7 m/min.(6 x 10-7 ft/min). In addition, the watershed was divided into four recharge zones that received 100, 75, 25, and zero percent of available recharge depending on topography of the grid cell. Grid cells with an elevation greater than 400 ft received 100 percent of total available recharge, whereas cells with an elevation less than 300 ft received no recharge and were considered areas of discharge. Insufficient data for Harps Creek and its tributaries required that parameters of riverbed conductivity, riverbed thickness, river stage heights, and river widths be estimated solely by calibration of the model.

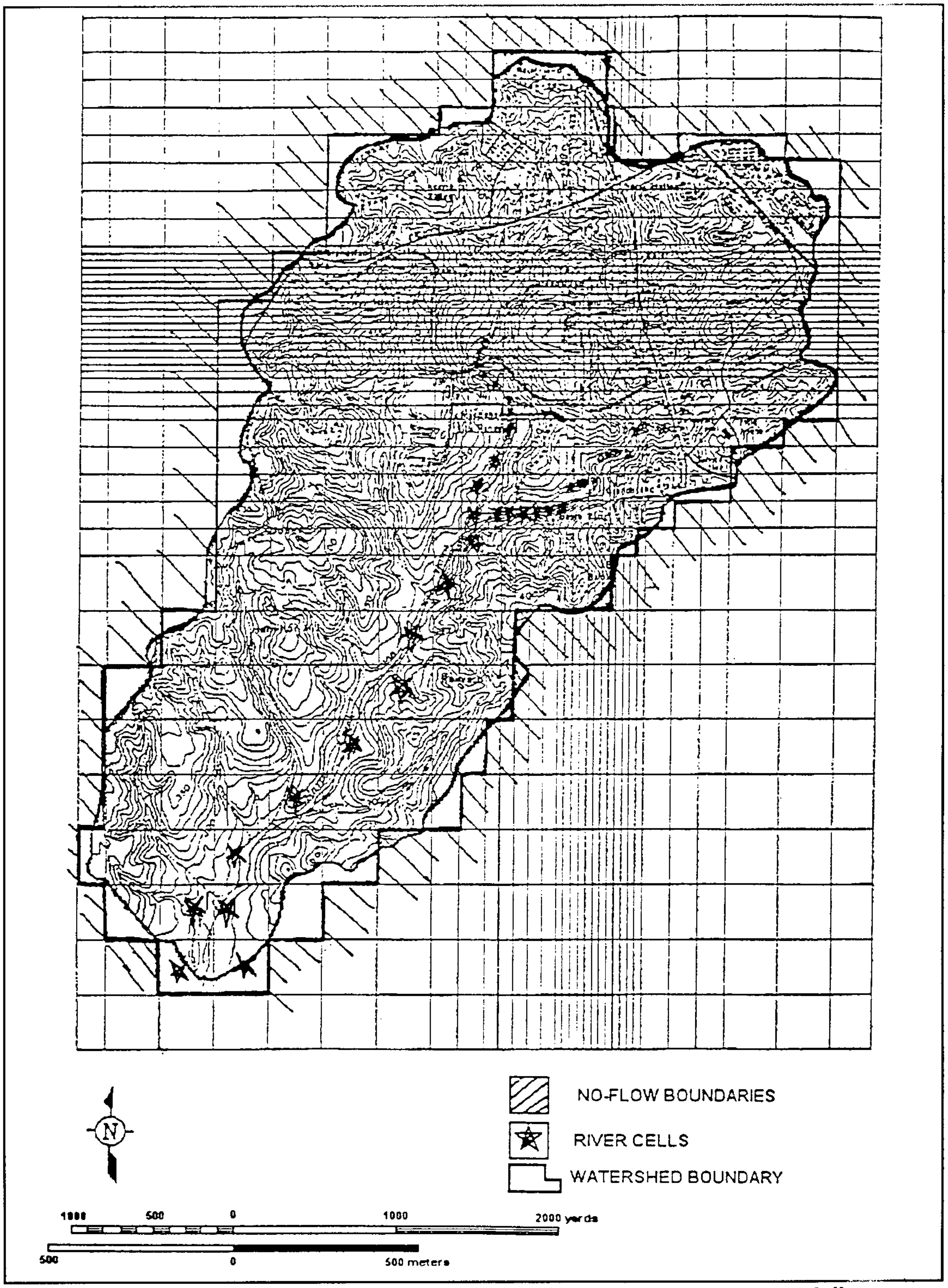


Figure 9. Discrete division of Harps Creek watershed for groundwater modeling.

Table 2. Hydraulic head values for the steady state model.

Node (i,j)	Well or Bore Hole	Measured Hydraulic Head (ft)	Simulated Hydraulic Head (ft)	Difference (hm - hs)
25,10	MW-1	356.93	353.71	3.22
32,10	BH-2	360.83	358.76	2.07
24,16	BH-3	348.79	350.00	-1.21
17,5	BH-4	347.56	347.70	-0.14
Mean Error (ME) = 0.985 ft Mean Absolute Error (MAE) = 1.66 ft Root Mean Squared (RMS) Error = 2.01 ft				

The calibrated model reached steady state conditions and reproduced all known hydraulic heads within acceptable values (Table 2). A contour map of computed watertable elevations in the watertable aquifer under steady state conditions (Figures 10 and 11) indicates a south-southwesterly direction of groundwater flow that is influenced strongly by topography and surface water drainage patterns. Due to uncertainties in calibration and parameter values used, the model may not represent the system accurately under a different set of boundary conditions or hydraulic stresses. Additional borings are needed to provide greater details of groundwater flow patterns at the site.

Simulations of different transient conditions were applied to the computer model to determine the effect of extreme rain events on the hydrologic flow regime of the site. Based on information from the U.S. Weather Bureau data, a 100-year return period storm with a 24-hour duration is 22.53 cm (8.87 in) of rainfall (Hershfield 1961) (Appendix Q). Rainfall was divided into six periods according to the SCE rainfall distribution for a 24-hour storm (Chow et al. 1988) with each period covering 4 hours. These amounts were entered uniformly as recharge rates to the site. Simulations were run using a recharge rate of 12 percent of available rainfall and a worse-case condition of 100 percent recharge of total rainfall infiltrated to the groundwater (Appendix R). In addition, specific yields of the aquifer were varied from 0.3, the maximum for a medium sand, to 0.07, an average for a sandy clay (Fetter 1988).

Results of these simulations showed that little change occurs in groundwater flow patterns from steady state to transient conditions. The difference between a recharge of 12 percent compared with a maximum recharge of 100 percent is one of magnitude rather than any significant change (Appendix S). The water table rose dramatically, as expected, from such a severe 24-hr/100-yr storm. Thus, groundwater flow rates increased dramatically. Other computer software programs specifically geared toward modeling the unsaturated zone must be used for a more complete picture of groundwater movement at the site.

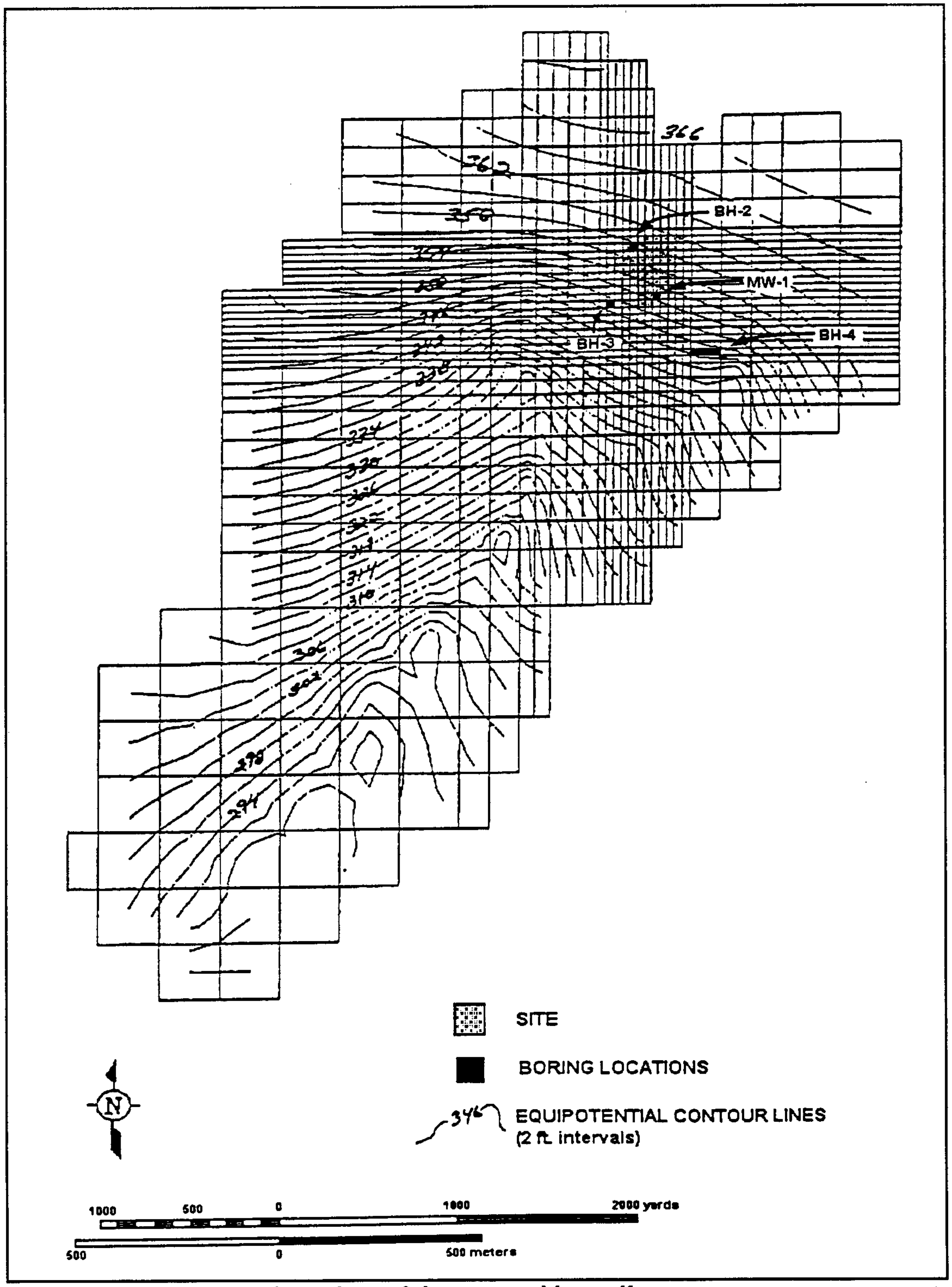


Figure 10. Potentiometric surface of the water table aquifer.

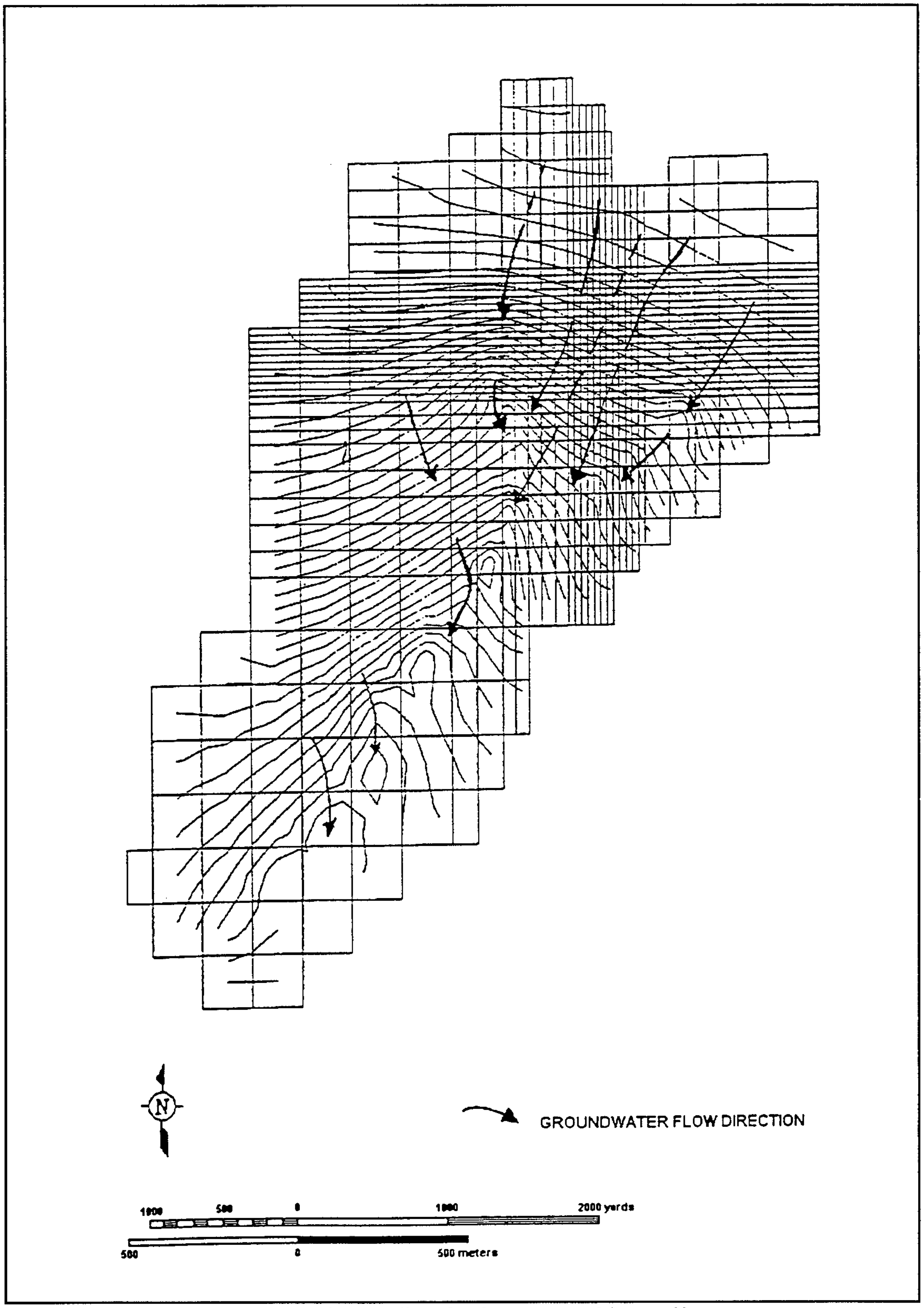


Figure 11. Direction of groundwater flow in the water table aquifer.

Summary and Conclusions

Proposed Fort Benning landfarm site consists of typical Coastal Plain sediments that are permeable and acidic with some clay and a mean grain size distribution of medium to fine sand. Site soils are a sandy clay loam with small values for CEC, organic content, and moisture content. No perched watertable was discovered during subsurface exploration to suggest the existence of a natural clay barrier or a confining unit with reduced permeability. The watertable is a subdued replica of topography with an unsaturated zone that probably is greater than 15.24 m (50 ft), even following extreme rainfall events. A small hydraulic gradient exists across the site that increases down gradient towards the streams. Groundwater flow is to the south-southwest. Evapo-transpiration rates as great as 70 percent of total yearly precipitation limits the amount of infiltrating water. Rainwater that does infiltrate travels primarily vertically to the watertable and then horizontally to downgradient creeks. Water bodies potentially affected by placement of a landfarm within this hydrogeologic system are Harps Creek and downgradient Oswichee Creek. Drinking water for the region is supplied primarily by a surface water source and a few rarely used wells that tap deep aquifers protected by a confining unit. Both types of water sources are upgradient with no known drinking water sources within 24.1 km (15 miles) downgradient from the site. Limitations of the Fort Benning subsurface can be overcome by construction of a clay and/or synthetic layer and use of soil enhancement techniques such as addition of lime and mineral nutrients to the soil.

Because shallow groundwater of the region flows directly into local creeks, the greatest concern is possible mobilization of landfarm contaminants by infiltrating rainwater that might reach the water table still in significant concentrations. These concerns are minimized by numerous studies conducted on the fate of hydrocarbons in the subsurface. Studies concluded that even poor quality soils similar to those at Fort Benning have the ability to greatly reduce petroleum concentration through retardation and biodegradation. Expectations of little to no migration of contaminants are further confirmed by documented experiences of the Fort Polk landfarm (Smith et al. 1992).

Landfarm technology has been researched thoroughly for a variety of environments and found to be a safe alternative even in imperfect sites. The contaminant potential of landfarm organics in the subsurface is based on the specific hydrogeology of the site, type of wastes incorporated, and management strategies of the landfarm. Reliable monitoring of the physical properties of the landfarm matrix, in addition to monitoring local creeks and groundwater, will

allow for rapid pollution detection at the Fort Benning landfarm and, consequently, adoption of management modifications to interrupt any possible migration process.

4 Subsurface Modeling

Field Data

Seven soil borings have been drilled at the site with soil samples taken every 1.5 m (5 ft). A split spoon sampler was used to classify the soils and to determine the groundwater elevation of each boring. Because of cost considerations, three borings were filled in after water elevation was determine; other four soil borings have been converted into monitoring wells. Sandy material with some thin clay layers predominated in the soil borings (Appendix L).

The four monitoring wells were logged using an induction conductivity log and a gamma log (Appendix T) to determine location of clay layers. Graphing of clay layers at their respective heights shows with some certainty that there is one continuous clay layer underneath the entire site (Appendix U). Undisturbed samples taken at the bottom of the four monitoring wells were test for in-situ density (pcf), moisture content, hydraulic conductivity, and soil characteristics (Table 3).

Modeling

The 2-dimensional computer modeling program used to simulate the flow of water and contaminates through saturated and unsaturated layers, FEMWATER and LEWASTE (Yeh and Chang, 1993a, b), were developed under the direction of the U.S. Army Corps of Engineers with support from the U.S. Department of Defense, the U.S. Department of Energy, and the U.S.

Table 3. Sample test results.

Boring No.	Sample Date	Depth (ft)	In-Situ Density (pcf)	Moisture Content (%)	Hydraulic Conductivity K (cm/s)	Soil Description
MW-1	13 Jun 94	102			1.8 x 10-4	Sand, trace clay, organic matter
MW-2	24 Oct 95	94-96	127.9	23.83	1.4 x 10-4	Silty sand, trace of clay, yellow
MW-3	23 Oct 95	74-76	107.54	7.3	8.5 x 10-4	Sand, some silt, trace of clay, yellow
MW-4	25 Oct 95	84-86	126.4	22.5	1.02 x 10-4	Silty sand, trace of clay, trans yellow

Environmental Protection Agency. Visualization of FEMWATER and LEWASTE were interfaced with a graphics software (Groundwater Modeling System (GMS)) package developed by the Engineering Computer Graphics Laboratory (ECGL) of Brigham Young University for the Department of Defense (GMS 1995). For purposes of viewing in GMS, the model was converted to a 3-dimensional model. This was accomplished by putting one 2-dimensional model 30.5 cm (1 ft) in back of the other. Using the GMS film loop, the simulation can be viewed showing the contamination plume in time increments of Table 4.

Table 4. Time increments.

Time in sec	Time
300	5 min
660	11 min
2203200	25.5 days
165210000	5.24 yr
375830016	11.9 yr
586460032	18.6 yr
797080000	25.3 yr
886600000	28.1 yr

A 2-dimensional grid was used for imputing into FEMWATER and LEWASTE. Grid was made up of a total of 2420 elements and 2520 nodes with 55 elements in the x-direction and 45 elements in the z-direction. Bottom nodes were set at an elevation of zero. Top nodes were set according to the surface elevation of the site with a maximum elevation of 4175.76 cm (137 ft). Grid was lined up in the direction of groundwater flow. At the bottom of the grid, spacing in z-direction was 365.76 cm (12 ft) while spacing at the top is (15.24 cm (0.5 ft). This was done to keep number of nodes to a minimum and create more definition of the 2-dimensional grid near the ground surface (Appendix V). Grid spacing in the x-direction is 2011.68 cm (66 ft), except near the site, where spacing is decreased to simulate a 152.4 cm (5 ft) clay wall for the site. For purposes of viewing in GMS, 2-dimensional grid was converted to a 3-dimensional grid by putting one 2-dimensional grid 30.48 cm (1 ft) in back of the other. The 3-dimensional grid is made up of 2420 elements and 5040 nodes. Front face of the elements is the same size as the 2-dimensional model.

A program without a clay liner placed under the treatment area, without natural occurring clay layers, and with all sand was set up to simulate a worst case scenario. Amount of rain normally infiltrating into the groundwater is 12 percent of annual rainfall (Kundell). An average rainfall of 124 cm/yr (48.8 in./yr) would create an infiltration rate of 14.87 cm/yr (5.856 in./yr). To create a worst case scenario, infiltration rate of rainwater was doubled to 29.748 cm/yr (11.712 in./yr). Test results from three undisturbed samples taken from monitoring wells (MW) 1, 2, and 4 had an average hydraulic conductivity (K) of 1.4 x 10-4 cm/s (2.76 x 10-4 ft/min). To further create a worst case scenario, hydraulic conductivity was increased to 5.8 x 10-3 cm/s (1.4 x 10-2 ft/min). Finally, two distribution coefficients (Kd) were used; the first Kd was set at 100 ml/g which would be a realistic value for soil at Fort Benning. The second Kd was set at 10

ml/g, for a worst case scenario. Smaller distribution coefficient allows contaminate plume to travel faster. Assumptions also included those made for FEMWATER and LEWASTE (Appendix W).

A second simulation added a clay layer with a hydraulic conductivity of 9.0 x 10-5 cm/s (1.77 x 10-4 ft/min) located 1828.8 cm (60 ft) below the surface of the site with an average thickness of 335.28 cm (11 ft) as suggested by the logs from the monitoring wells. This simulation also included an added clay liner 152.4 cm (5 ft.) thick creating a "pit" 106.68 cm (3.5 ft) deep and 11917.68 cm (391 ft) across with a hydraulic conductivity of 9.00x 10-8 (2.95 x 10-9 ft/s) where contaminated soil would be treated by "farming." Assumptions were made for FEMWATER and LEWASTE (Appendix W) and for the clay (Appendix X).

5 Conclusion

Simulations are not calibrated models; they are worst case scenarios. Simulation of treatment area without a layer can be compared to the simulation with a layer as to total distance contamination traveled in the z-direction. Soil was considered contaminated if this value was above 0.002, which is 0.2 percent of starting contamination. Using this comparison, contamination in simulation without the clay liner traveled 731.52 cm (24 ft), whereas contamination in the simulation with the liner traveled 396.24 cm (13 ft). Contamination in the simulation without a constructed barrier moved nearly twice the distance contamination moved with a clay layer over the 28.1 year period. However, this method of comparison may not be the most accurate interpretation because the soil becomes saturated in the simulation with the clay liner. Contamination moves very quickly through saturated soil and once it gets through the saturated zone it begins moving slower. Simulation without the clay liner depicts slow but steady movement that outpaces contamination in the simulation with a clay liner.

Another way to compare the simulations is to look at distance traveled by contamination beyond the depth of the clay liner. In the simulation with a clay liner, the contamination moved 144.78 cm (4.75 ft) beyond the liner. Simulation without a clay liner showed a movement of 480.06 cm. (15.75 ft) beyond the depth where the clay liner would have been located. Contamination in the simulation without the clay liner moved more than three times as far as in the simulation with the liner over the time period of 28.1 years.

Simulations are worst case scenarios for several reasons:

1. Hydraulic conductivity has been set higher than actual site conditions allowing water to travel through soil faster.

2. Program limitations assign the liner a hydraulic conductivity of 9.00 x 10-8 cm (2.95 x 10-9 ft/s), but geosynthetic clay liner may have a lower hydraulic conductivity.

3. Soil within the clay liner is fully saturated in the simulation, which will not be allowed under operating conditions. Soil being saturated creates a higher

concentration of contamination and increases speed at which the contamination plume moves within the clay liner.

4. Models do not have any decay factors that would simulate bioremediation that would take place.

5. Infiltration rate was doubled compared to expected amount.

6. Although the natural occurring clay layer, believed to be located 1828.8 cm (60 ft) below proposed landfarm surface, does not make a substantial difference in the simulation, it provides an added amount of security. A natural occurring clay layer would create an added barrier with the ability to trap contaminants because of the clay's cation exchange capacity (CEC).

This study concludes that the site Fort Benning, GA is suitable for a landfarm because of distance to groundwater, slow speed at which contaminants would travel in the unsaturated zone, and the added security that clay provides through cation exchange capacity.

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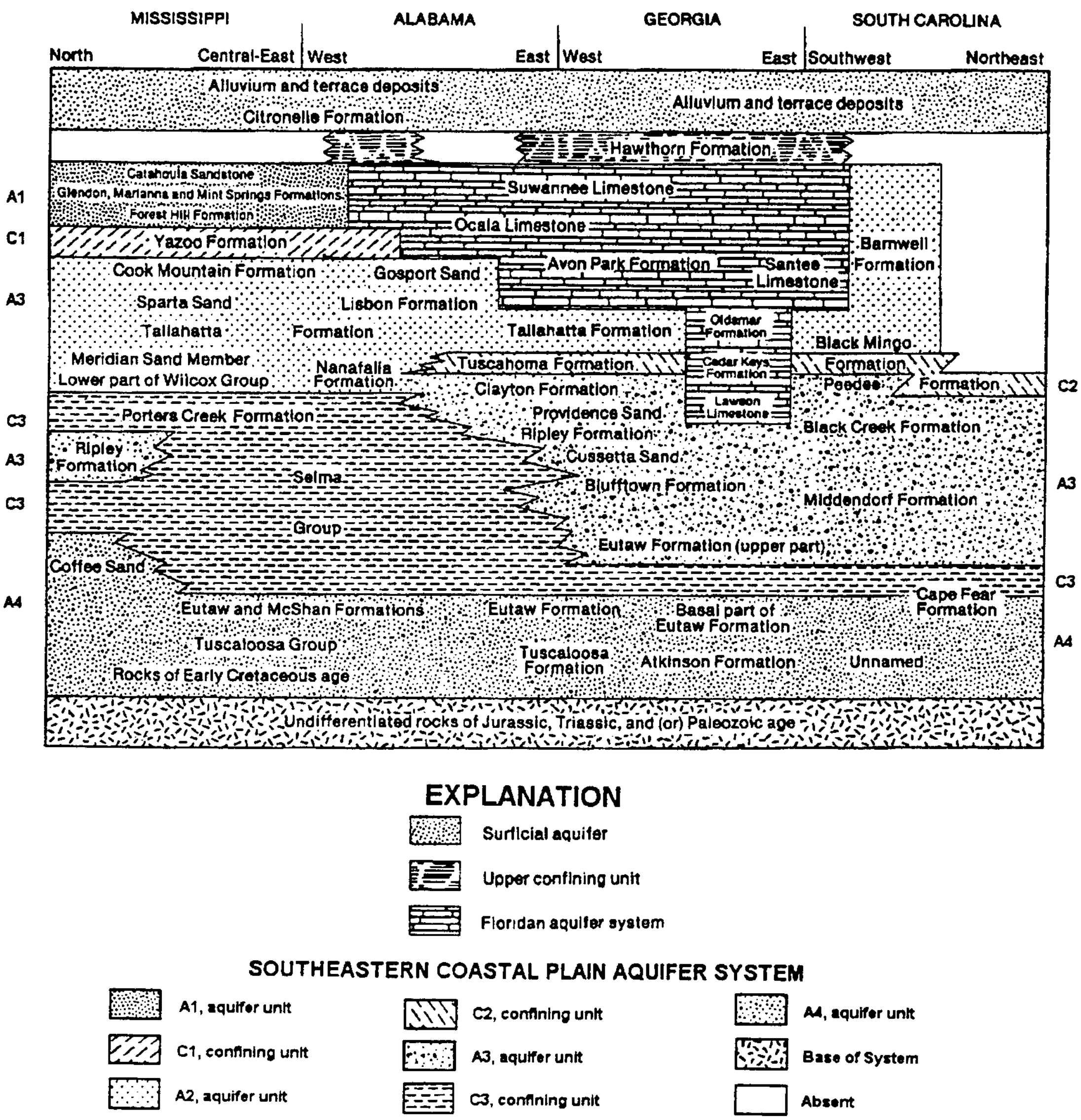
Appendix A: Loading Calculations

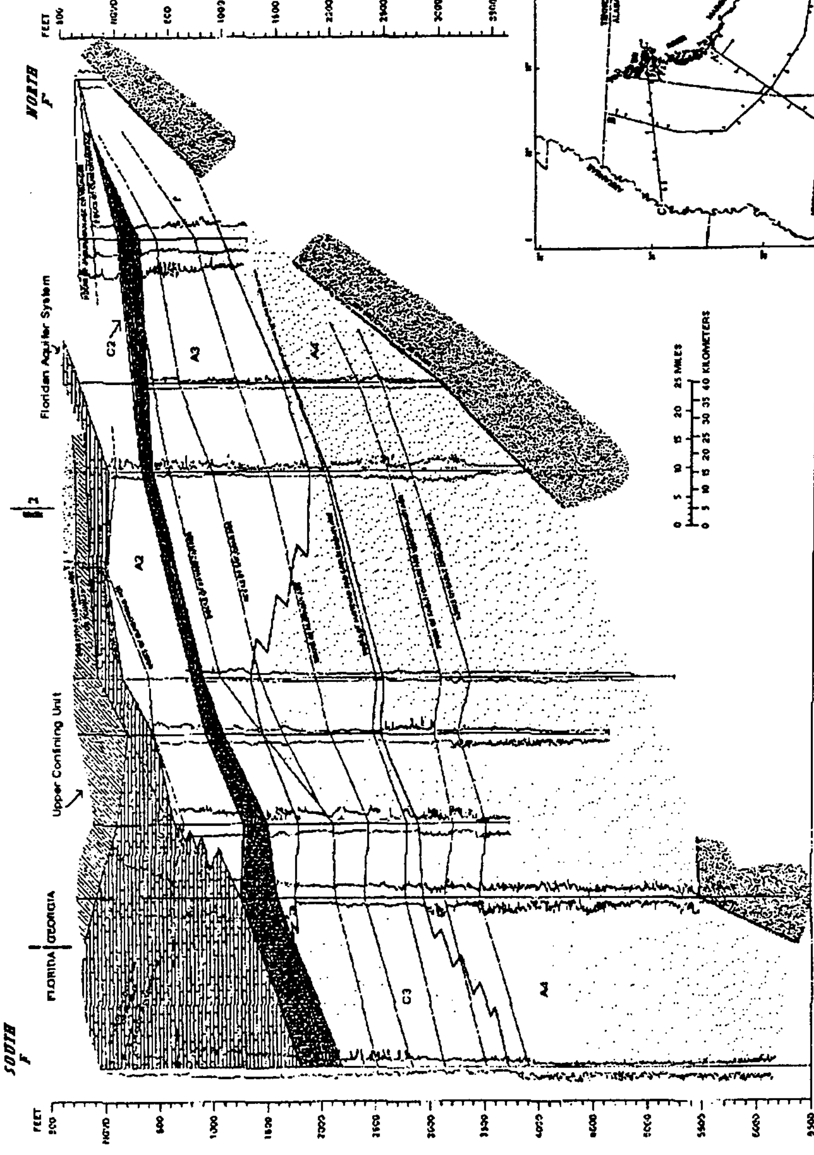
Estimated oily waste produced annually at Fort Benning:	**100,000** lbs
Allowable oily waste loading per application:	**1%**
Estimated treatment or actual "farming" area:	**5** acres
Estimated treatment area in square feet: 1 acre = 43,560 ft^2 43,560 ft^2 x 5 = 217,800 ft^2	**217,800** ft^2
Capacity of 6 inches (0.5 ft) of soil over 5 acres: 217,800 ft^2 x 0.5 ft = 108,900 ft^3	**108,900** ft^3
Estimated soil weight for 108,900 ft^3: 1 ft^3 of soil = 110 lbs 108,900 ft^3 x 110 lbs = 11,979,000 lbs	**11,979,000** lbs
Total capacity to assimilate oily waste at 1% application: 11,979,000 lbs x 0.01 = 119,790 lbs	**119,790** lbs
Estimated sludge loading annually at Fort Benning 500 yd^3 x 27 = 13,500 ft^3	**500** yd^3 **13,500** ft^3
Sludge weight per ft^3 13.500 ft^3 x 100	**100** lbs **1,350,000** lbs
Dry solid percentage 1,350,000 x .5 = 675,000 lbs	**0.5** % **675,000** lbs
Estimated treatment or actual "farming area" 675,000 lbs /5 = 135,000 lbs dry solids per acre	**5** acres **1135,000** lbs
Assuming 2.25% nitrogen content in dried sludge 135,000 lbs x .0225 = 3,037.5 lbs nitrogen per acre	**2.25%** **3,037.5** lbs

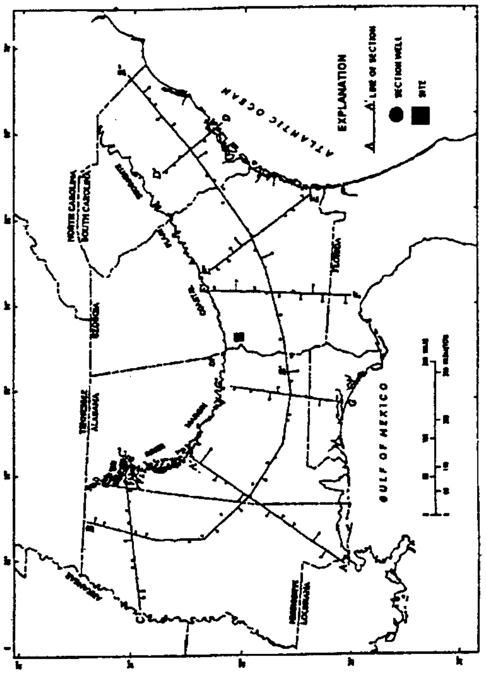
Appendix B: Southeastern Coastal Plain Stratigraphic Correlation Chart



(Source: Miller and Renken, 1988)

Generalized Hydrogeologic Section of Georgia





(Source: Renken *et al.* 1989)

Appendix C: Fort Benning Temperature, Wind Speed, and Humidity Data

Fort Benning Temperature, Wind Speed, and Humidity Data

	Temperature (F)		Wind Speed (mi/hr)		Relative Humidity
Month	**Mean Daily Max**	**Mean Daily Min**	**Mean**	**Max**	**Mean Percent**
January	59.0	36.0	5.8	48.3	59
February	61.0	39.0	5.8	55.2	56
March	68.0	44.1	6.9	70.2	52
April	78.1	52.2	5.8	55.2	49
May-	84.0	60.1	4.6	80.6	49
June	90.0	68.0	3.5	73.3	53
July	91.0	71.1	3.5	80.6	59
August	91.0	70.0	3.5	63.3	56
September	86.0	65.0	3.5	59.9	55
October	79.0	53.1	3.5	47.2	50
November	66.9	42.1	4.6	50.6	52
December	60.1	37.9	4.6	54.1	58
Annual	75.9	53.1	4.6	80.6	54
No. of Years on Record	32	32	34	32	33

Source: USTHAMA 1992 taken from USAF Air Weather Service Climatic Brief for Fort Benning, Georgia (Lawson AAF), period of record May 1939 to December 1972, with extremes updated through December 1981.

Appendix D: Yearly Precipitation Totals for Fort Benning Georgia

Yearly Precipitation Totals for Fort Benning, Georgia

Year	Amount (inches)		Year	Amount (inches)		Year	Amount (inches)
1960	45.76		1971	56.24		1982	51.89
1961	43.70		1972	51.90		1983	55.69
1962	**36.04**		1973	57.20		1984	38.20
1963	41.46		1974	45.99		1985	43.10
1964	64.37		1975	62.63		1986	39.21
1965	40.29		1976	52.02		1987	37.50
1966	58.76		1977	46.60		1989*	60.74
1967	46.28		1978	58.25		1990	39.93
1968	38.27		1979	**67.50**		1991	56.45
1969	39.25		1980	50.55		1992	47.27
1970	46.82		1981	47.31		1993	47.96

* Year 1988 had incomplete precipitation totals.

Smallest and largest yearly precipitation totals are in bold.

(Source: National Climate Center, Ashville, North Carolina)

Appendix E: Fort Benning Precipitation

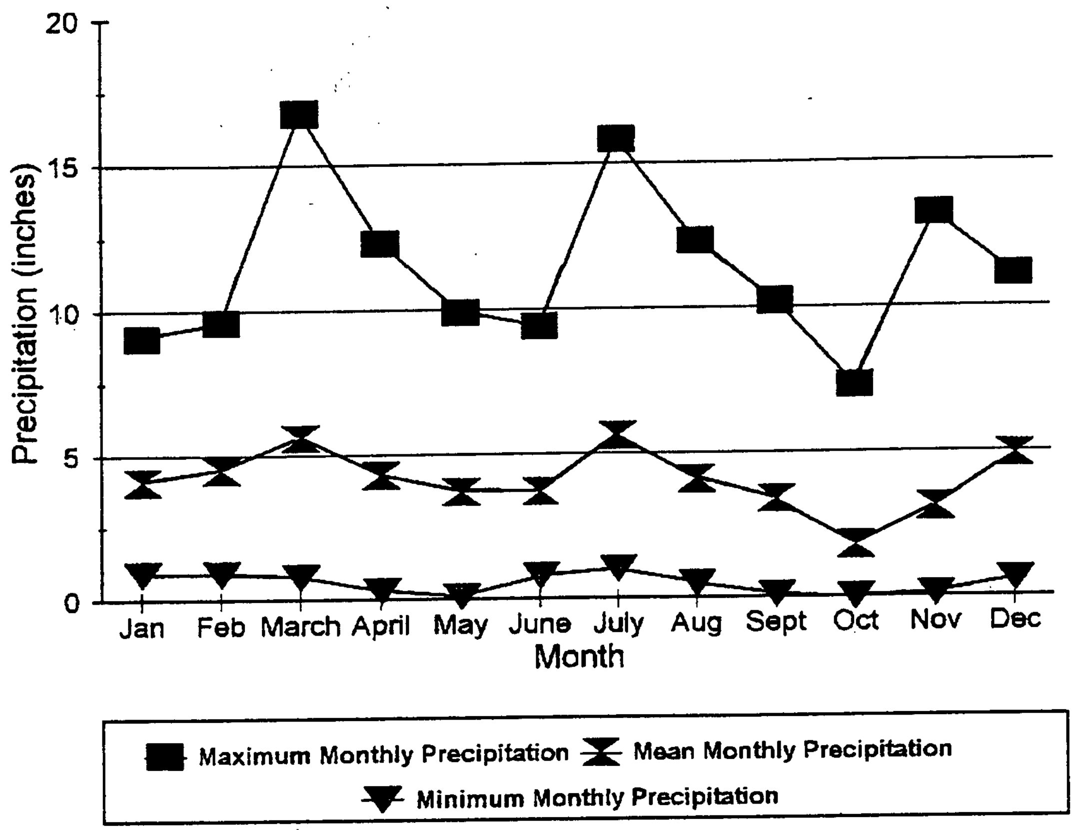
Fort Benning Precipitation

Month	Mean (in.)	Greatest (in.)	Least (in.)	Max 24-Hour (in.)
January	4.0	9.1	0.9	4.7
February	4.1	8.2	0.9	4.1
March	5.3	16.8	0.8	4.4
April	4.4	12.3	0.4	5.5
May	3.3	9.9	0.1	3.1
June	4.0	9.4	0.8	3.4
July	5.7	15.8	1.0	3.2
August	4.1	12.3	0.5	0.6
September	3.3	8.9	*	3.1
October	1.6	7.3	*	4.4
November	2.7	13.2	0.1	4.4
December	4.9	11.1	0.6	4.0
Annual	47.4	76.3	24.8	5.5

* Less than 0.04 inches

Source: USTHAMA 1992 taken from USAF Air Weather Service Climatic Brief for Fort Benning, Georgia (Lawson AAF), period of record May 1939 to December 1972, with extremes updated through December 1981

Appendix F: Average Monthly Precipitation for Fort Benning, GA



(Source: National Climate Center, Ashville, North Carolina
AWS Climatic Brief for Fort Benning, Georgia (Lawson AAF), period of record 1969 to 1993.)

Appendix G: Description of Water Quality Analysis

Two water samples were collected from each of the four boreholes and from a downgradient surface water source (Figure xx). Prior to collection of water samples, stagnant water was removed from the bore holes with a bailer (a well volume) and samples were taken from water that had refilled the well to its original level. One well volume was removed from boreholes and water samples were collected while the auger stem was still in place. MW-1 was purged with three well volumes removed prior to sampling. Redox potential, temperature, pH, and specific conductance of water samples were measure on-site. All sets of samples were maintained at a temperature below 4° C (39.2° F) with one set acidized for total iron concentration measurements. Samples then were transported to the U.S. Army CERL chemical laboratory where each was filtered and pH, specific conductance, and total iron were measured in addition to major anion and cation concentrations: HCO_3^-, Cl^-, NO_3^-, $SO_4^=$, NA^+, NH_4, K^+, Mg^{++}, and Ca^{++}.

Measurement of major anion and cation concentrations were made using chromatography analysis on a Waters LC-Module 1 solvent delivery system equipped with a Waters 431 conductivity detector. Data were collected and manipulated using a Dell 386 computer with Maxima 820 software. Standard solutions for all analyte ions were prepared by dilution from appropriate stock solutions and were used to generate calibrations curves. Sample analyte concentrations were determined by manipulation of Maxima software. Total iron concentrations were measured by atomic absorption analysis on a Perkin Elmer 303B Atomic Absorption Spectrophotometer. A blank as well as a fresh standard were run to create a calibration curve and samples were aspired and analyzed for iron.

Sample may have been affected by limited sampling methods, inadequate purging, or prior activity at the site. Limestone roadfill at the site may be the cause of increased levels of calcium, carbonate, and sulfate concentrations found in BH-2 sample. The acidic sample from BH-4 had an increased level of nitrate, which may indicated septic tank or other nutrition-causing contamination sources. Also, levels of iron in water sample may have been increased artificially when the samples were acidized prior to filtration. Small shifts in pH or Eh can cause great changes in iron solubility; thus, increasing quantities of iron go into solution as pH values drop below 4.8 (Hem 1985). Despite these sampling questions, trends are observable. Surface water and groundwater samples from MW-1 are similar. Their small dissolved solids content and similar fingerprints imply that they come from the same source, rainwater.

Appendix H: Water Quality Analysis

Sample ID Sampling Date	MW-1 6/17/94	BH-2 6/15/94	BH-3 6/15/94	BH-4 6/16/94	Surface 6/16/94
FIELD MEASUREMENTS					
temperature (°C)	21.6	26.9	23.5	22.6	22.8
specific conductance (µmhos/cm)	50	120	50	170	20
redox potential (mV)	208	- - -	295	201	110
LAB MEASUREMENTS					
pH (in lab on 6/21/94)	5.53	6.99	5.70	3.56	5.00
carbonate (mg/L)	5.04	47.7	16.5	3.4	4.93
chloride (mg/L)	10.1	5	4.79	22.4	4.87
nitrate (mg/L)	12.6	4.17	9.7	36.3	4.22
sulfate (mg/L)	5.22	24.9	8.46	12.5	4.88
sodium (mg/L)	2.76	4.78	2.52	7.74	1.72
ammonia (mg/L)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
potassium (mg/L)	0.67	1.28	0.88	0.78	0.62
magnesium (mg/L)	0.55	0.95	0.85	0.71	0.35
calcium (mg/L)	3.36	16.8	4.2	5.92	1.09
total iron (mg/L)	0.11	8.14	16.9	23.63	8.39

Conducted by the chemical laboratory of the U.S. Army Construction Engineering Research Laboratories, Champaign, Illinois.

Appendix I: Background Water Quality From a Landfill North of Site

Sample ID Lab # Sampling Date	K C4502 7/10/93	P C4541 7/9/93
GENERAL PARMETERS		
temperature (°C)	20.9	19.5
pH	3.5	3.9
specific conductance (μmhos/cm)	35	51
dissolved oxygen (ppm)	6.9	- - -
DISSOLVED METALS (mg/L)		
silver	< 0.010	< 0.010
arsenic	< 0.0010	< 0.0010
barium	< 0.010	0.013
beryllium	0.001	0.001
cadmium	< 0.0005	< 0.0005
cobalt	< 0.050	< 0.050
chromium	< 0.020	< 0.020
copper	< 0.025	< 0.025
mercury	0.000226	0.000347
nickel	0.000168	0.000433
lead	< 0.0010	0.0012
antimony	< 0.0005	< 0.0005
selenium	< 0.01	< 0.01
thallium	0.00146	< 0.0005
vanadium	< 0.050	< 0.050
zinc	< 0.015	0.399
TOTAL METALS (mg/L)		
silver	< 0.010	< 0.010
arsenic	< 0.0010	< 0.0010
barium	0.038	0.026
beryllium	0.001	0.001
cadmium	0.000897	0.00223
cobalt	0.072	< 0.050
chromium	< 0.020	- - -
copper	< 0.025	- - -
mercury	0.000459	< 0.0001
nickel	0.000253	0.000488
lead	0.0077	0.0202

Sample ID Lab # Sampling Date	K C4502 7/10/93	P C4541 7/9/93
TOTAL METALS continued (mg/L)		
antimony	< 0.0005	< 0.0005
selenium	< 0.01	< 0.01
thallium	<0.0005	< 0.0005
vanadium	< 0.050	< 0.050
zinc	0.067	- - -
NON-METALS INORGANICS		
ammonia (mg/L)	0.44	0.69
chloride (mg/L)	2.1	1.4
total cyanide (mg/L)	< 0.01	< 0.01
nitrite + nitrate as N (mg/L)	0.11	1.2
total organic carbon (mg/L)	0.99	1.3
total organic halogens (TOX) (µg/L)	20	29
sulfate (mg/L)	< 1.0	2.1
ORGANIC COMPOUNDS (µg/L)		
acetone	7*	< 4.4*
2-butanone	< 2	< 2
dichlorodifluoromethane	5	< 2
1,1-dichloroethane	< 2	< 2
1,1-dichloroethene	< 2	< 2
methylene chloride	< 2	< 2
tetrachloroethene	< 2	< 2
1,1,1-trichloroethane	< 2	< 2
trichlorofluoromethane	31	< 2
bis(2-ethylhexyl)phthalate	5**	7**
phenol	< 10	< 10

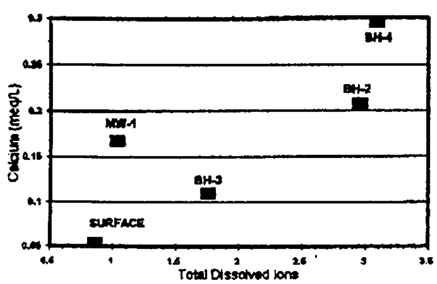
* Indicates that analyte was found in the associated blank as well as in the sample.

** indicates that the reported value is an estimate and that the analyte was found in the associated blank as well as in the sample.

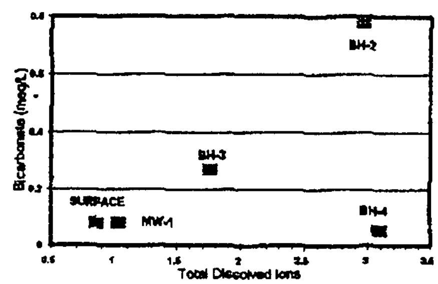
(Source: Meckelnburg 1993)

Appendix J: Water Analysis Scatter Diagram

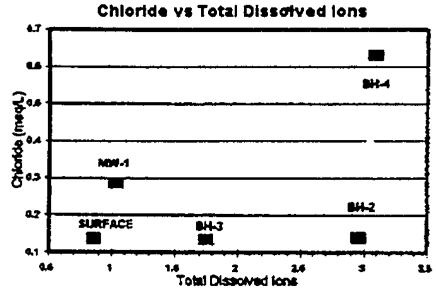
Calcium vs Total Dissolved Ions



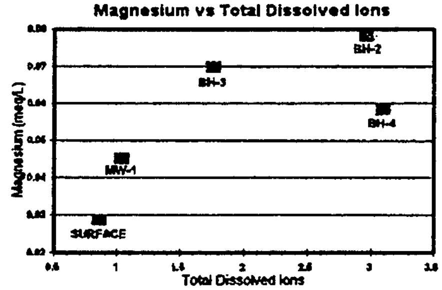
Bicarbonate vs Total Dissolved Ions



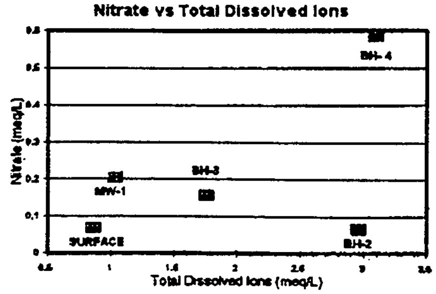
Chloride vs Total Dissolved Ions



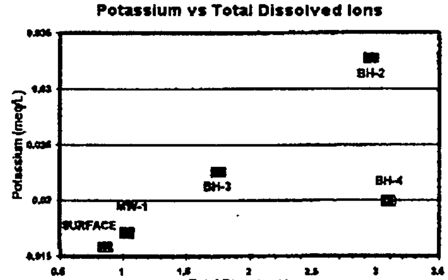
Magnesium vs Total Dissolved Ions



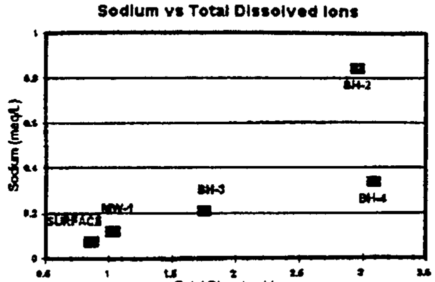
Nitrate vs Total Dissolved Ions



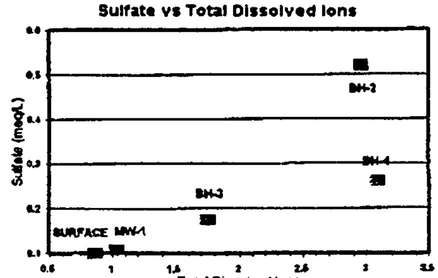
Potassium vs Total Dissolved Ions



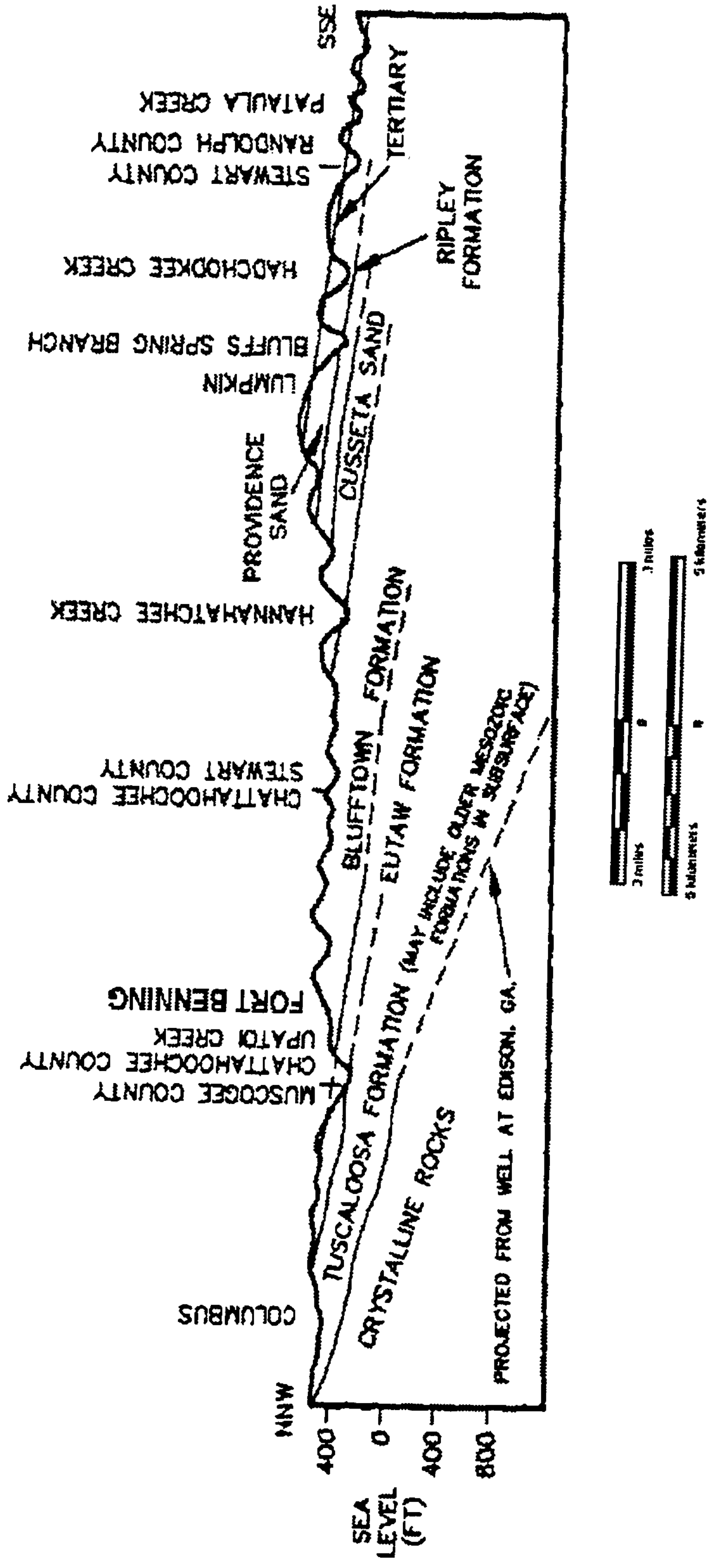
Sodium vs Total Dissolved Ions



Sulfate vs Total Dissolved Ions



Appendix K: Generalized Section, Muscogee to Randolph Counties



(Source: USATHAMA 1992)

Appendix L: 1994/1995 Drilling Logs

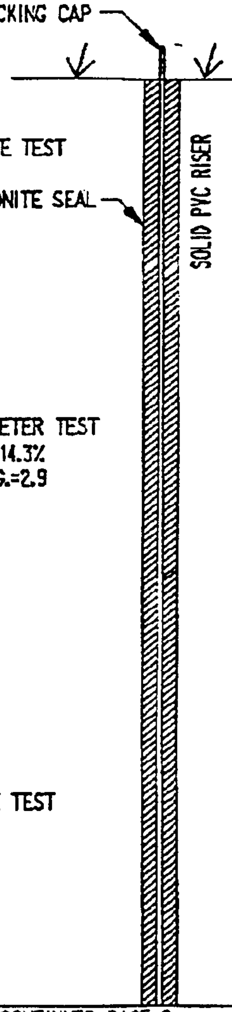
SHEET 1 OF 2

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-8802

LOG OF BORING

CONTRACTED WITH: U.S. ARMY CERL BORING NO.: B-1
PROJECT NAME: LAND FARM PROJECT, FT. BENNING JOB NO.: J00148 DATE: 06/13/94
DRILLER: BAILEY WARD, PIEDMONT ENVIRONMENTAL DRILLING RIG: CME 55 LOGGED BY: PDP

ELEV.	DESCRIPTION	DEPTH IN FEET	SAMPLES NO.	TYPE	BLOWS/6"	RECOV.	NOTES
	BROKEN ASPHALT						LOCKING CAP
	SAND-FINE TO MEDIUM; DRY; DENSE; RED-ORANGE (COASTAL SEDIMENT)	0	1		7-22-23	16"	
		5	2		11-14-15	16"	SEIVE TEST
							BENTONITE SEAL
	SAND-MEDIUM; DRY; FIRM; TAN-WHITE (COASTAL)	10	3		7-11-7	16"	
		15	4		7-10-9	18"	
	CLAY-STIFF, MOIST, GREY AND SAND-FIRM; TAN INTERBEDDED IN 1" TO 5" LAYERS	20	5		8-16-20	16"	HYDROMETER TEST w=14.3% S.G.=2.9
	SAND-FINE; DENSE; DRY; WHITE-TAN (COASTAL)	25	6		20-25-26	14"	
		30	7		24-32-36	18"	
		35	8		18-26-29	16"	
		40	9		16-23-18	18"	SEIVE TEST
		45	10		13-12-9	18"	
		50	11		29-49-35	16"	
	CONTINUED PAGE 2						CONTINUED PAGE 2



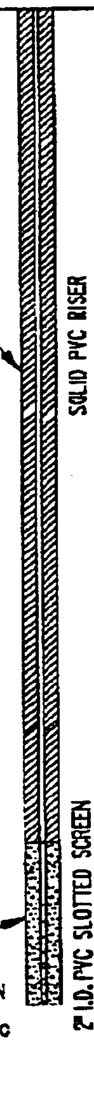
SHEET 2 OF 2

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0803 FAX 908-8802

LOG OF BORING

CONTRACTED WITH: U.S. ARMY CERL BORING NO.: B-1
PROJECT NAME: LAND FARM PROJECT, FT. BENNING JOB NO.: J00148 DATE: 06/13/94
DRILLER: BAILEY WARD, PIEDMONT ENVIRONMENTAL DRILLING RIG: CME 55 LOGGED BY: PDP

ELEV.	DESCRIPTION	DEPTH IN FEET	SAMPLES NO.	TYPE	BLOWS/6"	RECOV.	NOTES
		50					
			12	/	15-15-26	18"	
		55					
	TR. CLAY; RED-TAN-WHITE	60	13	/	12-17-17	14"	
		65	14	/	17-23-20	18"	SEIVE TEST
							BENTONITE SEAL
		70	15	/	12-14-20	12"	S.G.=2.7
			16	/	5-5-7	13"	HYDROMETER TEST S.G.=2.67 w=20.6%
	CLAY & SAND; FIRM; MOIST; TAN (COASTAL)	75					
	SAND-FINE; DENSE; DRY; TAN-WHITE (COASTAL)	80	17	/	17-21-23	18"	
		85	18	/	23-22-26	18"	
	TRACE CLAY; MOIST	90	19	/	6-6-7	14"	SEIVE TEST GROUNDWATER AT 92' 6-14-94
							TOP OF SAND PACK
	WET	95	20	/	10-13-18	18"	
							TOP OF SCREEN
	SAND-TR.CLAY, ORGANIC MATTER	100	21	/	6-9-11	16"	SAND PACK
			UD-1	X		22"	BOTTOM OF SCREEN
	BORING TERMINATED AT 102'						K_v = 1.8 x 10^{-4} cm/sec n=47%, S.G.=2.67
		105					



SHEET 1 OF 2

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-6802

LOG OF BORING

CONTRACTED WITH: U.S. ARMY CERL BORING NO.: B-2
PROJECT NAME: LAND FARM PROJECT, FT. BENNING JOB NO.: J00148 DATE: 06/14/94
DRILLER: BAILEY WARD, PIEDMONT ENVIRONMENTAL DRILLING RIG: CME 55 LOGGED BY: DLW

ELEV.	DESCRIPTION	DEPTH IN FEET	SAMPLES NO.	TYPE	BLOWS/6"	RECOV.	NOTES
	SAND-TR. CLAY;MEDIUM;LOOSE;BROWN (FILL)	0	1		2-1-4	12"	SEIVE TEST w=9.2%
	SAND-FINE TO MED;FIRM TO DENSE; RED-BROWN (COASTAL) W/1" TO 3" CLAY SEAMS	5	2		19-17-16	16"	
		10	3		8-13-14	16"	
		15	4		8-10-10	18"	SEIVE TEST w=4.0%
		20	5		13-17-17	18"	
	SOME CLAY	25	6		9-10-10	18"	HYDROMETER w=16.1% S.G.=2.9%
		30	7		7-6-9	18"	
		35	8		6-6-4	16"	
		40	9		13-7-6	18"	
	TRACE CLAY	45	10		13-15-10	18"	SEIVE TEST w=9.6%
		50	11		14-14-23	16"	
	CONTINUED, SHEET 2						

SHEET 2 OF 2

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1758 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0503 FAX 908-8802

LOG OF BORING

CONTRACTED WITH: U.S. ARMY CERL BORING NO.: B-2
PROJECT NAME: LAND FARM PROJECT, FT. BENNING JOB NO.: J00148 DATE: 06/14/94
DRILLER: BAILEY WARD, PIEDMONT ENVIRONMENTAL DRILLING RIG: CME 55 LOGGED BY: DLW

ELEV.	DESCRIPTION	DEPTH FEET	SAMPLES NO.	TYPE	BLOWS/6"	RECOV.	NOTES
		50					
		55	12	/	8-10-9	18"	
		60	13	/	25-17-10	12"	
		65	14	/	18-11-6	18"	
	CLAY-FIRM;MOIST;GREY (COASTAL)						
	SAND-TR. CLAY; MEDIUM; TAN; (COASTAL)	70	15	/	5-2-3	12"	SEIVE TEST w=31.8%
							GROUNDWATER AT 70.5'-6/14/94
	-NO CLAY	75	16	/	14-10-5	10"	
		80	17	/	15-32-22	4"	SEIVE TEST w=11.0%
	BORING TERMINATED AT 80'						
		85					
		90					
		95					
		100					
		105					

SHEET 1 OF 2

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1738 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-8802

LOG OF BORING

CONTRACTED WITH: U.S. ARMY CERL BORING NO.: B-3
PROJECT NAME: LAND FARM PROJECT, FT. BENNING JOB NO.: JD0148 DATE: 06/15/94
DRILLER: BAILEY WARD, PIEDMONT ENVIRONMENTAL DRILLING RIG: CME 55 LOGGED BY: DLW

ELEV.	DESCRIPTION	DEPTH IN FEET	SAMPLES NO.	TYPE	BLOWS/6"	RECOV.	NOTES
	CLAY-V. STIFF; MOTTLED RED-WHITE (COASTAL)	0	1	/	6-10-12	12"	HYDROMETER w=23.2%
	SAND-TR. CLAY; FIRM TO DENSE; RED-BROWN (COASTAL)	5	2	/	14-14-13	16"	
		10	3	/	6-10-9	16"	SEIVE TEST w=19.4%
	TAN	15	4	/	6-11-13	18"	
		20	5	/	6-18-17	18"	
		25	6	/	8-10-10	18"	
	SOME CLAY; VERY DENSE	30	7	/	18-49-49	18"	SEIVE TEST w=6.3%
		35	8	/	28-55-49	16"	
		40	9	/	20-13-10	18"	
		45	10	/	12-16-20	18"	
	SOME CLAY	50	11	/	9-11-14	16"	SEIVE TEST HYDROMETER w=17.6%
	CONTINUED, SHEET 2						

SHEET 2 OF 2

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0803 FAX 908-8802

LOG OF BORING

CONTRACTED WITH: U.S. ARMY CERL BORING NO.: B-3

PROJECT NAME: LAND FARM PROJECT, FT. BENNING JOB NO.: J00148 DATE: 06/15/94

DRILLER: BAILEY WARD, PIEDMONT ENVIRONMENTAL DRILLING RIG: CME 55 LOGGED BY: DLW

ELEV.	DESCRIPTION	DEPTH IN FEET	SAMPLES NO.	TYPE	BLOWS/6"	RECOV.	NOTES
		50					
	DENSE, RED-BROWN	55	12	/	22-23-19	16"	
	FIRM; TAN	60	13	/	14-12-16	18"	
		65	14	/	10-9-10	16"	
	5" CLAY LAYER, MOIST	70	15	/	9-9-12	14"	HYDROMETER w=30.1%
		75	16	/	15-10-11	12"	
		80	17	/	12-7-9	18"	
	SOME CLAY; DENSE; WET	85	18	/	29-25-21	10"	SEIVE TEST w=18.1%
	▽	90	19	/	19-22-20	6"	GROUNDWATER AT 88.5' AT BORING COMPLETION
		95	20	/	4-9-10	5"	
	BORING TERMINATED AT 95'	100					
		105					

SHEET 1 OF

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-8802

LOG OF BORING

CONTRACTED WITH: U.S. ARMY CERL BORING NO.: B-4
PROJECT NAME: LAND FARM PROJECT, FT. BENNING JOB NO.: J00148 DATE: 06/14/94
DRILLER: BAILEY WARD, PIEDMONT ENVIRONMENTAL DRILLING RIG: CME 55 LOGGED BY: DLW

ELEV.	DESCRIPTION	DEPTH IN FEET	SAMPLES NO.	TYPE	BLOWS/6"	RECOV.	NOTES
	SAND-TR. CLAY; MEDIUM; LOOSE TO DENSE; TAN, RED-BROWN (COASTAL)	0	1		1-2-7	12"	
		5	2		6-14-13	18"	
		10	3		10-13-17	16"	
	CLAY-V. STIFF; RED-BROWN-GREY (COASTAL)	15	4		9-11-13	18"	
		20	5		18-24-19	12"	
	SAND-FINE TO MEDIUM; FIRM; GREY; (COASTAL)	25	6		6-7-7	16"	
	WHITE, PINK	30	7		7-10-9	14"	SEIVE TEST w=8.6%
	TAN	35	8		9-13-13	18"	
		40	9		6-9-11	18"	
	SOME CLAY	45	10		7-9-7	18"	SEIVE TEST HYDROMETER S.G.=2.75 w=10.3%
	NO CLAY	50	11		14-14-8	16"	
	CONTINUED, SHEET 2						

SHEET 2 OF 2

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0808 FAX 908-8802

LOG OF BORING

CONTRACTED WITH: U.S. ARMY CERL BORING NO.: B-4

PROJECT NAME: LAND FARM PROJECT, FT. BENNING JOB NO.: J00148 DATE: 06/14/94

DRILLER: BAILEY WARD, PIEDMONT ENVIRONMENTAL DRILLING RIG: CME 55 LOGGED BY: DLW

ELEV.	DESCRIPTION	DEPTH IN FEET	SAMPLES NO.	SAMPLES TYPE	SAMPLES BLOWS/6"	SAMPLES RECOV.	NOTES
		50					
	TR. CLAY	55	12	/	9-9-10	18"	
	CLAY-SOME SAND; V. STIFF; GREY-WHITE (COASTAL)	60	13	/	6-9-12	18"	SEIVE TEST HYDROMETER w=35%
	SAND-TRACE CLAY; FINE; FIRM; WET; TAN (COASTAL)	65	14	/	5-5-10	16"	GROUNDWATER AT 58' AT BORING COMPLETION
	BORING TERMINATED AT 65'						
		70					
		75					
		80					
		85					
		90					
		95					
		100					
		105					

Appendix M: Geologic Description of Borings

Samples described by Marilyn Weiss, October 1994
Color Descriptions from Geological Society of America Rock-Color Chart, 1963. All depths refer to depth below surface.

BORING 1 (MW-1)			
Bed #	**Depth**	**Sample No.**	**Description**
1	Surface	1	Clayey sand, light brown (5 YR 5/6), fine grained, subangular quartz, micaceous, some white material (possibly gypsum)
2	5 ft	2	Sand, grayish orange (10 YR 7/4), medium to fine grained, subangular to sub-rounded quartz, micaceous, slightly carbonaceous, come clay aggregates.
3	10 ft	3	1 inch clay layer variegated in color greenish gray (5 GY 6/1), dark yellowish orange (10 YR 6/6), and dark reddish brown (10 R 3/4), micaceous. Clayey sand, light brown (5 YR 5/6), medium to fine grained, subangular quartz, micaceous
		4	1 inch of clay layer, light greenish gray (5 GY 8/1), banded by dark reddish brown (10 R 3/4), micaceous
	15 ft		Sand, moderate brown (10 YR4/4), medium grained subangular quartz, micaceous, small ferruginous clay nodules.
4	15 ft	5	Clayey sand, grayish orange (10 YR 7/4), medium to fine grained, subangular to subrounded quartz, micaceous
		6	Clayey sand, very pale orange (10 YR 8/2), minimally mottled with moderate brown (5 YR 4/4) and dark yellowish orange (10 YR 6/6) fine grained, subrounded quartz, small pieces of mica.
		7	Clayey sand, dark yellowish orange (10 YR 6/6) minimally mottled with very pale orange (10 YR8/2) and moderate brown (5 YR4/4) fine grained, subrounded quartz, small pieces of mica
		8	Clayey sand, dark yellowish orange (10 YR 6/6), mottled with very pale orange (10 YR8/2) and moderate brown (5 YR4/4) fine grained. subrounded quartz, small pieces of mica.
	35 ft		Narrow layer of clay, less than one-half inch, light olive gray (5 Y 6/1).
5	40 ft	9	Sand, very pale orange (10 YR 8/2), fined grained, subangular, quartz, large pieces of mica, small clay aggregates comprising less than 2 percent

BORING 1 (MW-1) continued			
Bed #	**Depth**	**Sample No.**	**Description**
6	45 ft	10	Clayey sand, dark yellowish orange (10 YR 6/6), mottled with very pale orange (10 YR8/2) and moderate brown (5 YR4/4) fine grained, subrounded quartz, clay ferruginous nodules of darker color moderate brown (5 YR 3/4), some mica.
		11	Clayey sand, dark yellowish orange (10 YR 6/6), mottled with very pale orange (10 YR8/2) and moderate brown (5 YR4/4) fine grained, subrounded quartz, small pieces of mica.
	55 ft	12	Clayey sand, mostly moderate brown (5 YR 4/4) mottled with dark yellowish orange (10 YR 6/6) and the darker moderate brown (5 YR 3/4), fine grained, subrounded quartz, clay ferruginous nodules of the darker colors, some mica.
7	60 ft	13	Sand, grayish orange (10 YR 7/4), medium to coarse grained, poorly sorted, subangular quartz, micaceous, small darker aggregates of quartz, clay, and mica
8	65 ft	14	Clayey sand, heavily mottled with moderate reddish orange (10 R 6/6), moderate red (5 R 4/6), dark yellowish orange (10 YR 6/6), moderate brown (5 YR 4/4), and very pale orange (10 YR 8/2), medium to fine grained subangular quartz, micaceous, ferruginous clay nodules of darker colors.
		15	Clayey sand, mostly dark reddish brown (10 R 3/4) mottled with moderate reddish brown (10 R 4/6), moderate reddish orange (10 R 6/6) and traces of dark yellowish orange (10 YR 6/6) medium to fine grained, subangular quartz, ferruginous clay nodules of darker colors.
		16	Sandy clay, light brown (5 YR 5/6), medium to fine grained subangular quartz, micaceous, clay aggregates.
		17	Clayey sand, dark yellowish orange (10 YR 6/6), mottled with very pale orange (10 YR8/2) and moderate brown (5 YR4/4) fine grained, subrounded quartz, small pieces of mica.
	85 ft	18	Clayey sand, dark yellowish orange (10 YR 6/6), mottled with very pale orange (10 YR8/2) and moderate brown (5 YR4/4), fine grained, subrounded quartz, small pieces of mica.
9	90 ft	19	Sand, grayish orange (10 YR 7/4), coarse to fine grained, subangular to subrounded quartz, micaceous, poorly sorted, some small clay aggregates.
10	95 ft	20	Clayey sand, dark yellowish orange (10 YR 6/6), fine grained, subrounded quartz, micaceous.
11	100 ft	21	Silty sand, mottled light gray (N 7) and medium dark gray (N 4), very fine grained, quartz, micaceous, with large pieces approximately 1 to 2 cm in length of organic matter (carbonize).

BORING #2 (BH-2)			
Bed #	**Depth**	**Sample No.**	**Description**
1	Surface	1	Sand, white (N 9), subangular quartz, medium to fine grained, some small clay aggregates.
2	5 ft	2	Sandy clay, moderate reddish brown (10 R 4/6), with mottlings of dark yellowish orange (10 YR 6/6) and moderate brown (5 YR 4/4), medium to fine grained, subangular quartz, ferruginous, micaceous
3	10 ft	3	1 inch clay layer variegated in color greenish gray (5 GY 6/1), dark yellowish orange (10 YR 6/6) and dark reddish brown (10 R 3/4), micaceous. Clayey sand, dark yellowish orange (10 YR 6/6) and heavily mottled with moderate brown (5 YR 4/4), very pale orange (10 YR 8/2), and some pale reddish brown (10 R 5/4), medium to fine grained subangular quartz, micaceous, some clay aggregates of darker colors.
4	15 ft	4	Sand, white (N 9), fined grained, subangular, quartz, very micaceous, some clay aggregates and quartz darker in color comprising less than 2 percent.
5	20 ft	5	Sand, pale red (10 R 6/2), medium grained subangular quartz, micaceous, some small clay aggregates.
6	25 ft	6	Clayey sand, grayish red (5 R 4/2) mixture of ferruginous clay nodules of very dusky red purple (5 RP 2/2) surrounded by a mixture of grayish red purple (5 RP 4/2) and dark yellowish orange (10 YR 6/6) medium grained subrounded quartz.
7	30 ft	7	Clayey sand to sandy clay, dark yellowish orange (10 YR 6/6), clay layers of greenish gray (5 GY 6/1), variegated with dark yellowish orange (10 YR 6/6), fine grained, subrounded quartz, small pieces of mica.
		8	Clayey sand to sandy clay, light brown (5 YR 5/6), fine grained quartz, micaceous.
	40 ft	9	Clayey sand to sandy clay, dark yellowish orange (10 YR 6/6), mottled with very pale orange (10 YR8/2) and moderate brown (5 YR4/4), fine grained, subrounded quartz, small pieces of mica.
8	45 ft	10	Sand, white (N 9), medium grained, subangular, quartz, micaceous, some clay aggregates darker in color and comprising less than 2 percent.
9	50 ft	11	Clayey sand to sandy clay, dark yellowish orange (10 YR 6/6), mottled with very pale orange (10 YR8/2) and moderate brown (5 YR4/4), fine grained, subrounded quartz, small pieces of mica.
		12	Clayey sand, dark yellowish orange (10 YR 6/6), mottled with very pale orange (10 YR8/2) and moderate brown (5 YR4/4) fine grained, subrounded quartz, small pieces of mica.
		13	Clayey sand, very pale orange (10 YR 8/2), mottled with moderate brown (5 YR 4/4) and dark yellowish orange (10 YR 6/6) fine grained, subrounded quartz, small pieces of mica.

BORING #2 (BH-2) continued			
Bed #	**Depth**	**Sample No.**	**Description**
9 cont'd	65 ft	14	Clayey sand to sandy clay, light brown (5 YR 5/6) mottled with dark yellowish orange (10 YR 6/6) and moderate brown (5 YR 3/4), 2 inch layer of clay, medium grained quartz, micaceous, some clay aggregates darker in color.
10	70 ft	15	Sand light brown (5 YR 5/6) medium to coarse grained subangular quartz, small clay aggregates darker in color, micaceous.
11	75 ft	16	Clayey sand, dark yellowish orange (10 YR 6/6) medium to coarse grained subangular quartz, some clay aggregates.
12	80 ft	17	Sand, white (N 9), coarse to medium grained subangular to subrounded quartz, small clay aggregates of darker color.

BORING #3 (BH-3)			
Bed #	**Depth**	**Sample No.**	**Description**
1	Surface	1	Clay, micaceous, variegated greenish gray (5 GY 6/1) with light brown (5 YR 5/6), with some dark reddish brown (10 R 3/4), micaceous, some quartz
2	5 ft	2	Sand, grayish orange (10 YR 7/4), medium to very fine grained, subangular to subrounded quartz, micaceous, some small clay aggregates darker in color.
3	10 ft	3	Sand, very pale orange (10 YR 8/2), medium to fined grained, poorly sorted, subangular, quartz, very micaceous with some large pieces of mica, some clay aggregates darker in color and comprising less than 2 percent
4	15 ft	4	Clayey sand, pale red (10 R 6/2), fine grained to very fine grained, subangular to subrounded quartz, micaceous
	20 ft	5	Clayey sand, pale red (10 R 6/2), fine to very fine grained, subangular to subrounded quartz, micaceous, with clay nodules of grayish red purple (5 RP 4/2).
5	25 ft	6	Clayey sand, dark yellowish orange (10 YR 6/6), mottled with very pale orange (10 YR8/2) and moderate brown (5 YR4/4) fine grained, subrounded quartz, small pieces of mica.
6	30 ft	7	Clayey sand, pale red (10 R 6/2), fine grained, subangular quartz, micaceous, clay aggregates in darker colors.

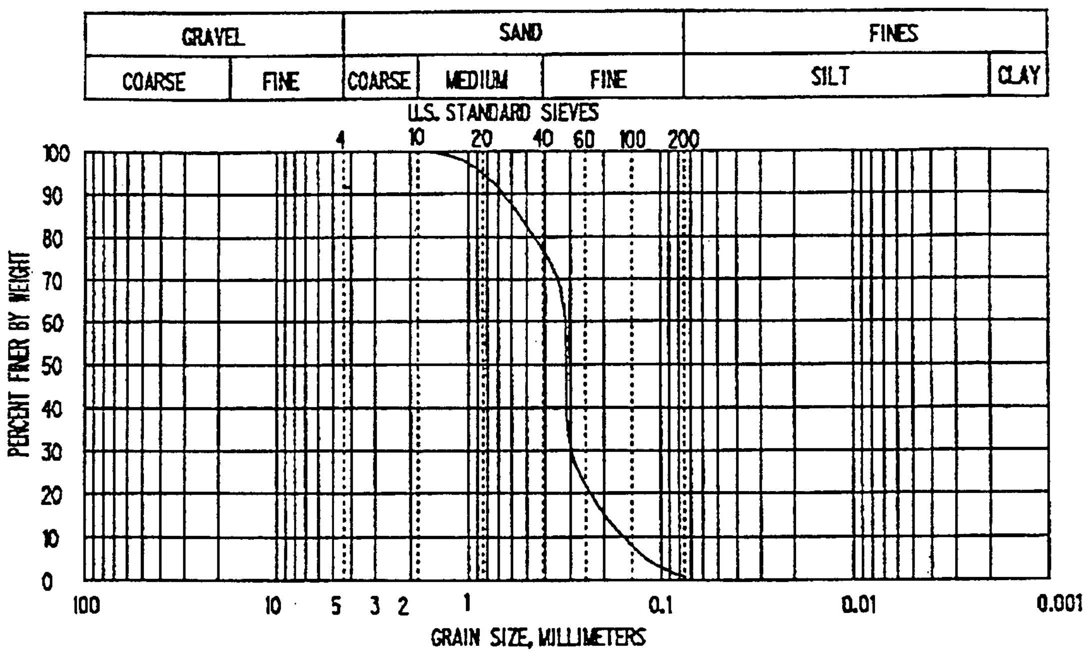
BORING #3 (BH-3) continued			
Bed #	**Depth**	**Sample No.**	**Description**
7	35 ft	8	Clayey sand, light brown (5 YR 5/6) with mottlings of moderate red (5 R 4/6), dark yellowish orange (10 YR 6/6), and moderate brown (5 YR 4/4), fine grained, subrounded quartz, small pieces of mica.
		9	Clayey sand, mostly moderate brown (5 YR 3/4) with mottling of light moderate brown (5 YR 4/4), fine grained, subrounded quartz, ferruginous, small pieces of mica.
	45 ft	10	Clayey sand, dark yellowish orange (10 YR 6/6), mottled with very pale orange (10 YR8/2) and moderate brown (5 YR4/4) fine grained, subrounded quartz, small pieces of mica.
8	50 ft	11	Sand, dark yellowish orange (10 YR 6/6), medium to fine grained, poorly sorted, subrounded to subangular quartz, micaceous, clay aggregates of 1 to 2 mm in size.
9	55 ft	12	Clayey sand, moderate reddish brown (10 R 4/6), fine grained, subangular quartz, ferruginous, small pieces of mica.
10	60 ft	13	Clayey sand, dark yellowish orange (10 YR 6/6), mottled with very pale orange (10 YR8/2) and moderate brown (5 YR4/4) fine grained, subrounded quartz, small pieces of mica.
		14	Clayey sand, dark yellowish orange (10 YR 6/6), mottled with very pale orange (10 YR8/2) and moderate brown (5 YR4/4) fine grained, subrounded quartz, small pieces of mica.
		15	Clayey sand to sandy clay, light brown (5 YR 5/6) mottled with dark yellowish orange (10 YR 6/6) and moderate brown (5 YR 3/4), 2 inch layer of clay, medium grained quartz, micaceous, some small clay aggregates of darker colors.
	cont'd	16	Clayey sand, light brown (5 YR 5/6).fine grained quartz, micaceous, ferruginous.
10	80 ft	17	Clayey sand to sandy clay, dark yellowish orange (10 YR 6/6) mottled with light brown (5 YR 5/6) and moderate brown (5 YR 4/4), fine grained quartz, clay aggregates, some small pieces of mica.
11	85 ft	18	Sand, very pale orange (10 YR 8/2), fined grained, subangular, quartz, large pieces of mica, small clay aggregates of darker colors comprising less than 2 percent
12	90 ft	19	Clayey sand, small layer of grayish red purple (5 RP 4/2) mostly light brown (5 YR 5/6) with mottlings of very pale orange (10 YR 8/2) and dark yellowish orange (10 YR 6/6), fine grained, subangular to subrounded quartz, micaceous
	95 ft	20	Clayey sand, dark yellowish orange (10 YR 6/6) mottled with very pale orange (10 YR 8/2) and moderate brown (5 YR 4/4), fine grained, subrounded quartz.

BORING #4 (BH-4)			
Bed #	**Depth**	**Sample No.**	**Description**
1	Surface	1	Sandy clay, moderate brown (5 YR 4/4), subrounded quartz, fine grained.
		2	Sandy clay, moderate brown (5 YR 4/4), with striations of greenish gray (5 GY 6/1), subrounded quartz, fine grained.
		3	Sandy clay, moderate brown (5 YR 4/4), with striations of greenish gray (5 GY 6/1), subrounded quartz, fine grained.
	15	4	Clay, very light gray (N 8) with dark yellowish orange (10 YR 6/6) striations with moderate brown (5 YR 4/4) clayey sand fine grained, subangular to subrounded quartz, micaceous.
3	20 ft	5	Clayey sand, dark yellowish orange (10 YR 6/6) mottled with very pale orange (10 YR 8/2) and moderate brown (5 YR 4/4), fine grained, subrounded quartz.
	25 ft	6	Clayey sand, dark yellowish orange (10 YR 6/6) mottled with very pale orange (10 YR 8/2) and moderate brown (5 YR 4/4), fine grained, subrounded quartz.
4	30 ft	7	Sand, white (N 9), fine grained, subangular, quartz, very micaceous.
5	35 ft	8	Clayey sand, dark yellowish orange (10 YR 6/6) mottled with very pale orange (10 YR 8/2) moderate brown (5 YR 4/4), and some moderate reddish brown (10 R 4/6) fine grained, subrounded quartz.
	40 ft	9	Clayey sand, dark yellowish orange (10 YR 6/6) mottled with very pale orange (10 YR 8/2) and moderate brown (5 YR 4/4), fine grained, subrounded quartz.
6	45 ft	10	Sand, very pale orange (10 YR 8/2), medium grained, subangular quartz, micaceous, small clay aggregates.
7	50 ft	11	Clayey sand, dark yellowish orange (10 YR 6/6) mottled with very pale orange (10 YR 8/2) and moderate brown (5 YR 4/4), fine grained, subrounded quartz.
	55 ft	12	Clayey sand, dark yellowish orange (10 YR 6/6) mottled with very pale orange (10 YR 8/2) moderate brown (5 YR 4/4), and some moderate reddish brown (10 R 4/6) fine grained, subrounded quartz, small pieces of mica
8	60 ft	13	Sand, light brown (5 YR 6/4) poorly sorted, coarse to medium grained subangular to subrounded quartz, micaceous, clay aggregates.
9	65 ft	14	Clay, mottled dark yellowish orange (10 YR 6/6) with greenish gray (5 GY 6/1), micaceous.

Appendix N: Grain Size Analysis

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-8802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-1, S-2
PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



PERCENT PASSING: #4 100 %
#10 100
#40 74.2
#60 21.5
#100 7.4
#200 0.5

SOIL DESCRIPTION: SAND
USCS CLASS: SP
SOIL ORIGIN: COASTAL SEDIMENT
SOIL COLOR: RED-ORANGE
SPECIFIC GRAVITY:
MEDIAN SIZE (D50) 0.21 MM

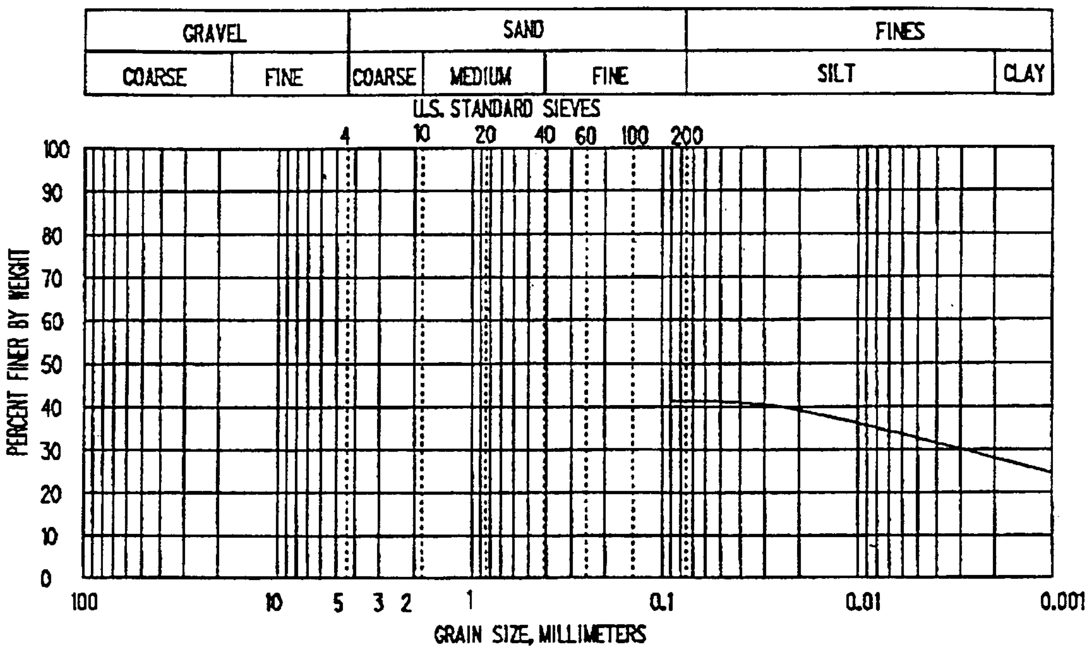
GRAIN SIZE CURVE

MECHANICAL SEIVE

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-8802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-1, S-5
PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



SOIL DESCRIPTION: SAND-CLAYEY
USCS CLASS: SC
SOIL ORIGIN: COASTAL SEDIMENT
SOIL COLOR: TAN
SPECIFIC GRAVITY: 2.9
MEDIAN SIZE (D50) N/A

GRAIN SIZE CURVE

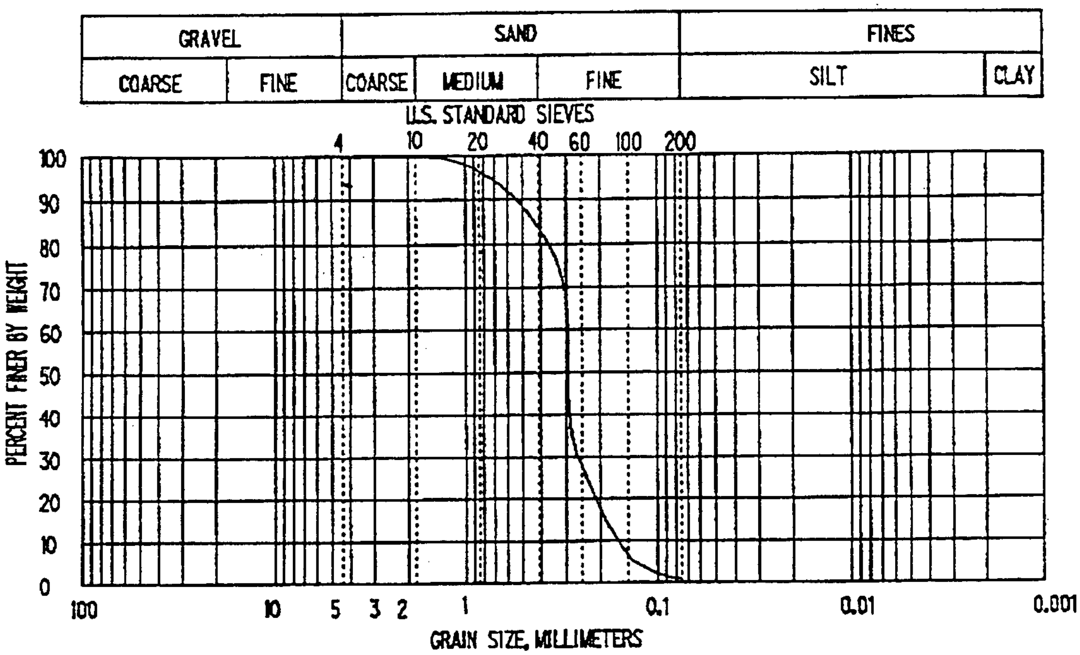
HYDROMETER ONLY

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-8802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-1, S-9

PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



PERCENT PASSING: #4 100 %
#10 100
#40 83.3
#60 29.2
#100 5.8
#200 0.8

SOIL DESCRIPTION: SAND
USCS CLASS: SP
SOIL ORIGIN: COASTAL SEDIMENT
SOIL COLOR: WHITE-TAN
SPECIFIC GRAVITY:
MEDIAN SIZE (D50) 0.3 MM

GRAIN SIZE CURVE

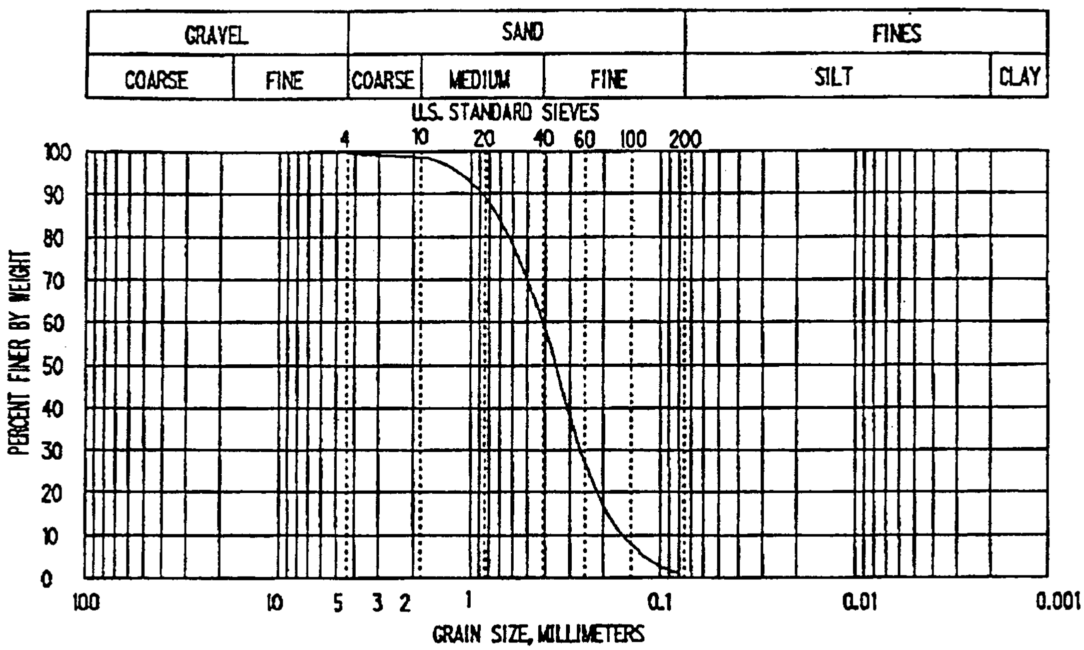
MECHANICAL SEIVE

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-8802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-1, S-13

PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



PERCENT PASSING: #4	100 %	SOIL DESCRIPTION:	SAND-TRACE CLAY
#10	99.2	USCS CLASS:	SP
#40	60.4	SOIL ORIGIN:	COASTAL SEDIMENT
#60	27.7	SOIL COLOR:	RED-TAN-WHITE
#100	8.5	SPECIFIC GRAVITY:	
#200	1.2	MEDIAN SIZE (D50)	0.35 MM

GRAIN SIZE CURVE

MECHANICAL SEIVE

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1796 MONTREAL CIRCLE, SUITE A
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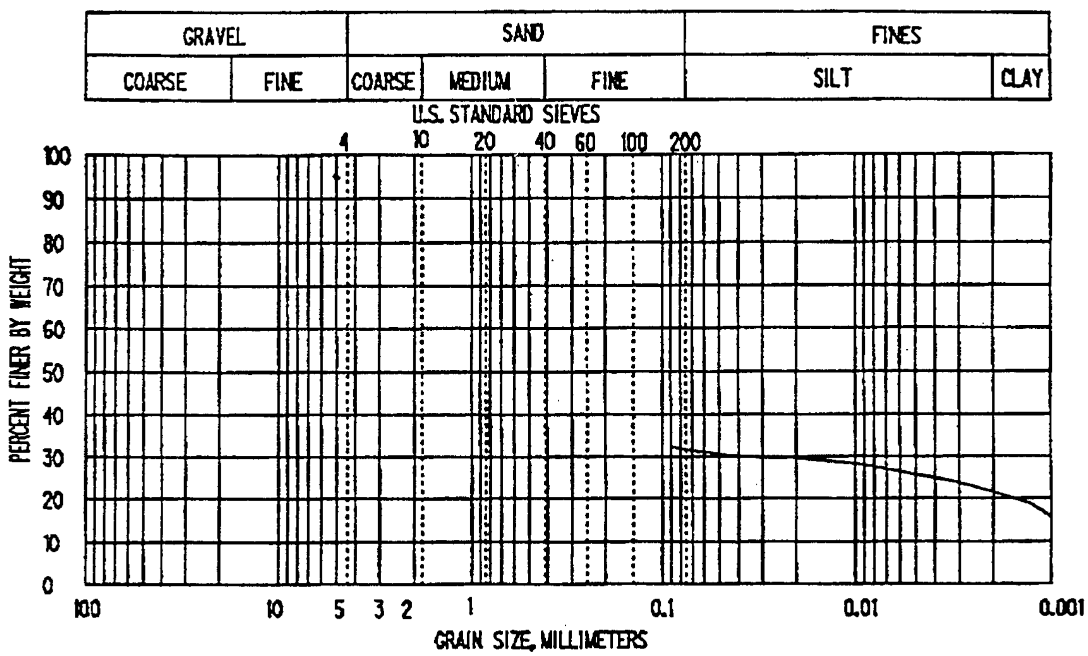
404 - 908-0809 FAX 908-6802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-1, S-16
PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



SOIL DESCRIPTION: SAND-SOME CLAY
USCS CLASS: SC
SOIL ORIGIN: COASTAL SEDIMENT
SOIL COLOR: TAN-WHITE
SPECIFIC GRAVITY: 2.67

GRAIN SIZE CURVE

HYDROMETER ONLY

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

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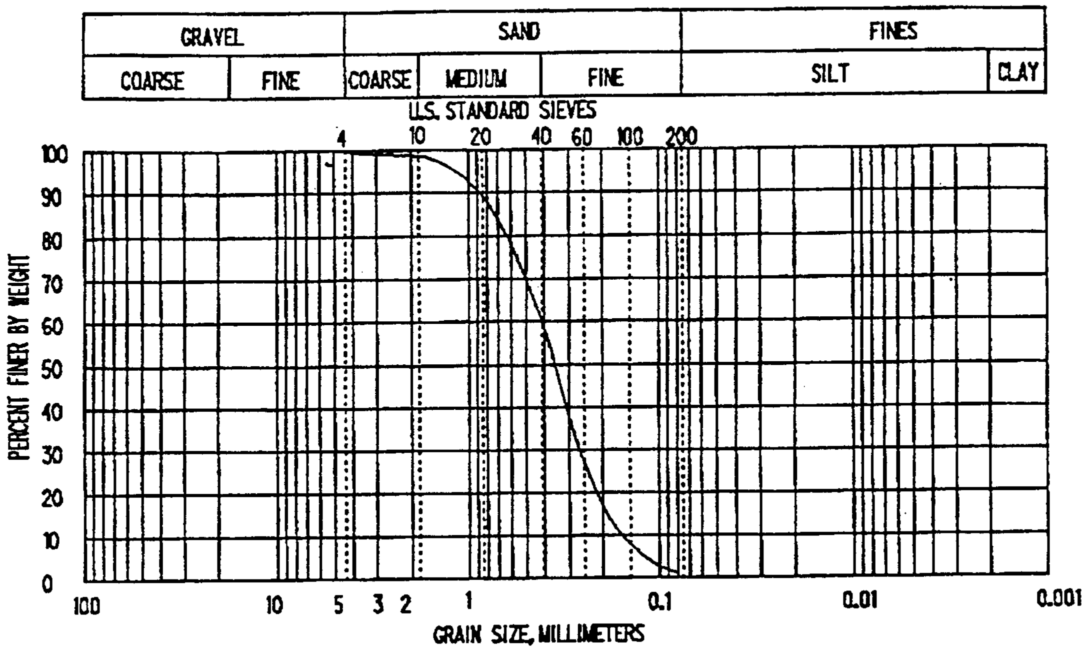
CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-1, S-19
PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



PERCENT PASSING: #4	100 %	SOIL DESCRIPTION:	SAND-TRACE CLAY
#10	99.4	USCS CLASS:	SP
#40	58.5	SOIL ORIGIN:	COASTAL SEDIMENT
#60	25.1	SOIL COLOR:	TAN-WHITE
#100	7.5	SPECIFIC GRAVITY:	
#200	2.0	MEDIAN SIZE (D50)	0.35 MM

GRAIN SIZE CURVE

MECHANICAL SEIVE

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
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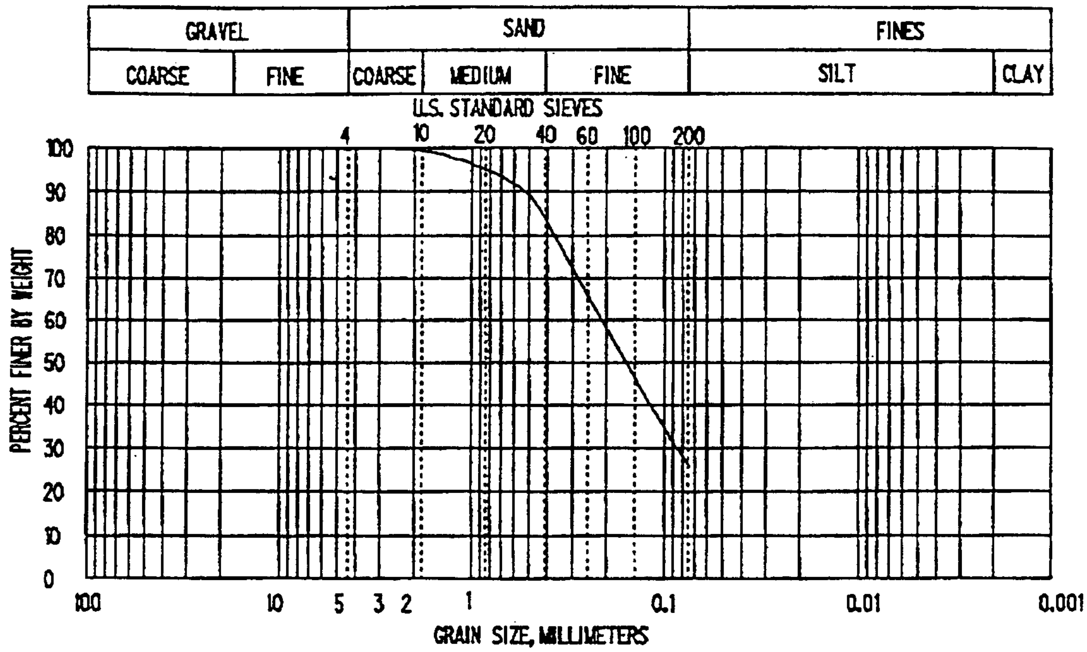
CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-2, S-1
PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



PERCENT PASSING:	#4	100 %	SOIL DESCRIPTION:	SAND-SOME CLAY
	#10	99.6	USCS CLASS:	SC
	#40	85.2	SOIL ORIGIN:	COASTAL SEDIMENT
	#60	64.4	SOIL COLOR:	BROWN
	#100	46.1	SPECIFIC GRAVITY:	
	#200	36.0	MEDIAN SIZE (D50)	0.17 MM

GRAIN SIZE CURVE

MECHANICAL SEIVE

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
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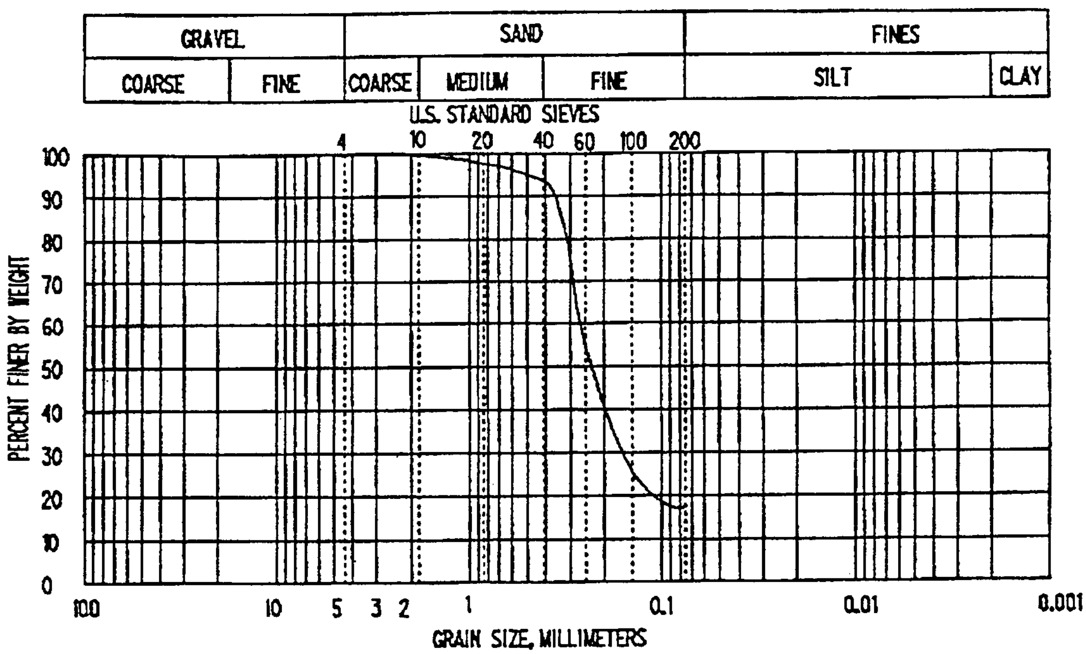
404 - 908-0809 FAX 908-8802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-2, S-4
PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



PERCENT PASSING:			
#4	100 %	SOIL DESCRIPTION:	SAND-SOME CLAY
#10	100	USCS CLASS:	SC
#40	94.7	SOIL ORIGIN:	COASTAL SEDIMENT
#60	54.5	SOIL COLOR:	RED-BROWN
#100	27.4	SPECIFIC GRAVITY:	
#200	18.7	MEDIAN SIZE (D50)	0.14 MM

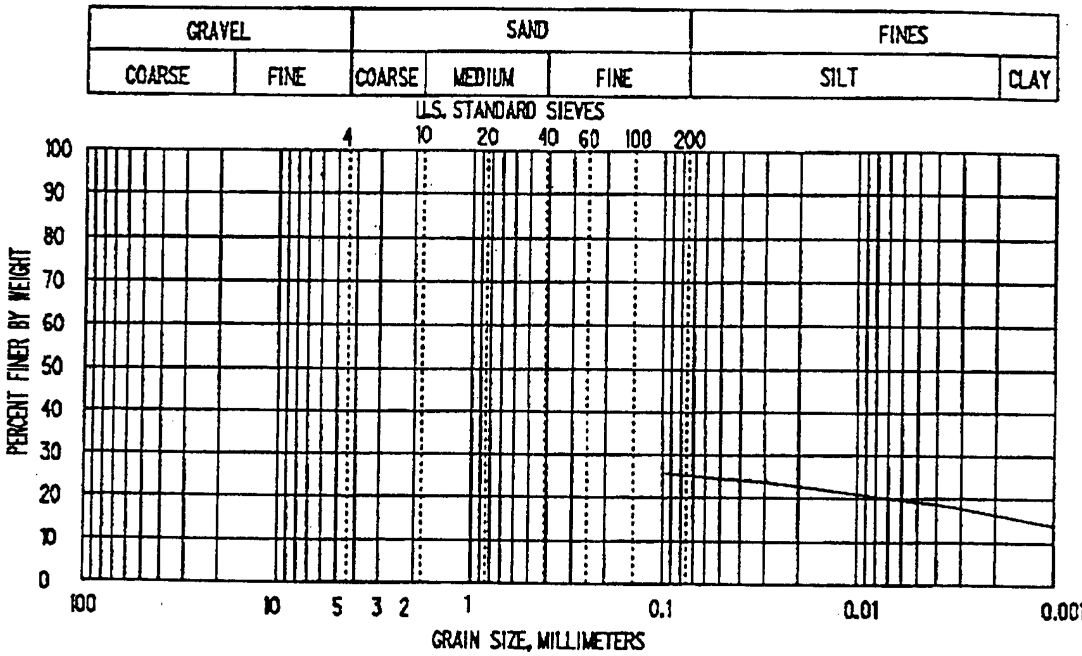
GRAIN SIZE CURVE

MECHANICAL SEIVE

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-8802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-2, S-6
PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



SOIL DESCRIPTION:	SAND-SOME CLAY
USCS CLASS:	SC
SOIL ORIGIN:	COASTAL SEDIMENT
SOIL COLOR:	WHITE-GREY
SPECIFIC GRAVITY:	2.9
MEDIAN SIZE (D50)	N/A

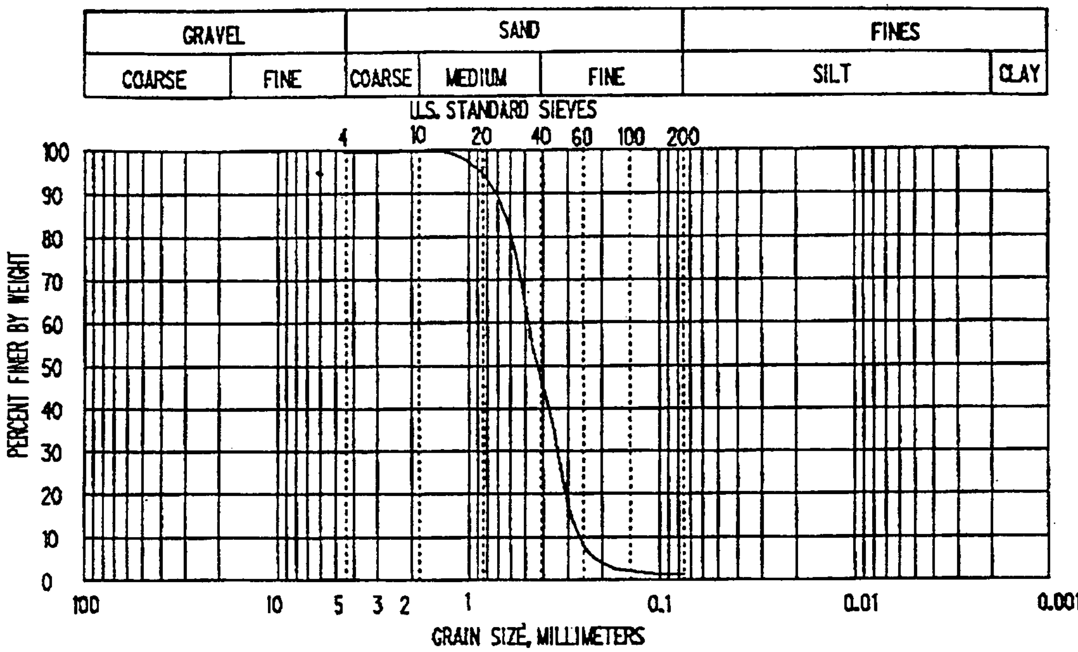
GRAIN SIZE CURVE

HYDROMETER ONLY

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-6802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-2, S-10
PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



PERCENT PASSING: #4	100 %	SOIL DESCRIPTION:	SAND
#10	100	USCS CLASS:	SP
#40	43.8	SOIL ORIGIN:	COASTAL SEDIMENT
#60	7.8	SOIL COLOR:	RED-BROWN
#100	2.1	SPECIFIC GRAVITY:	
#200	0.4	MEDIAN SIZE (D50)	0.41 MM

GRAIN SIZE CURVE

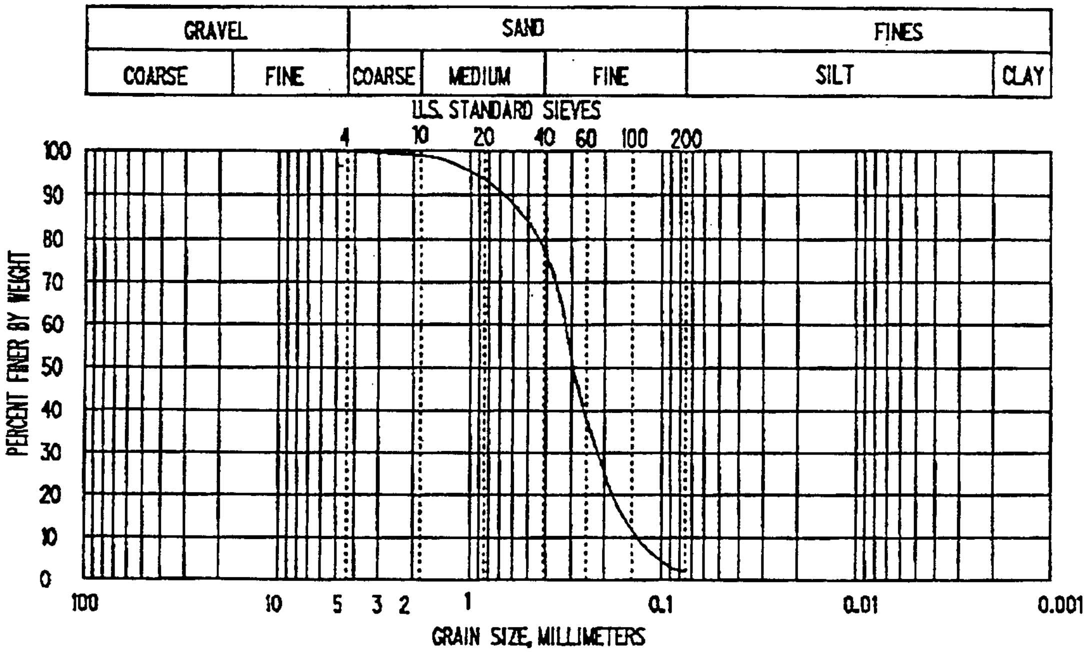
MECHANICAL SEIVE

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-6802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-2, S-15

PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



PERCENT PASSING: #4	100 %	SOIL DESCRIPTION:	SAND-TRACE CLAY
#10	99.0	USCS CLASS:	SP
#40	78.7	SOIL ORIGIN:	COASTAL SEDIMENT
#60	39.6	SOIL COLOR:	TAN
#100	10.4	SPECIFIC GRAVITY:	
#200	2.5	MEDIAN SIZE (D50)	0.3 MM

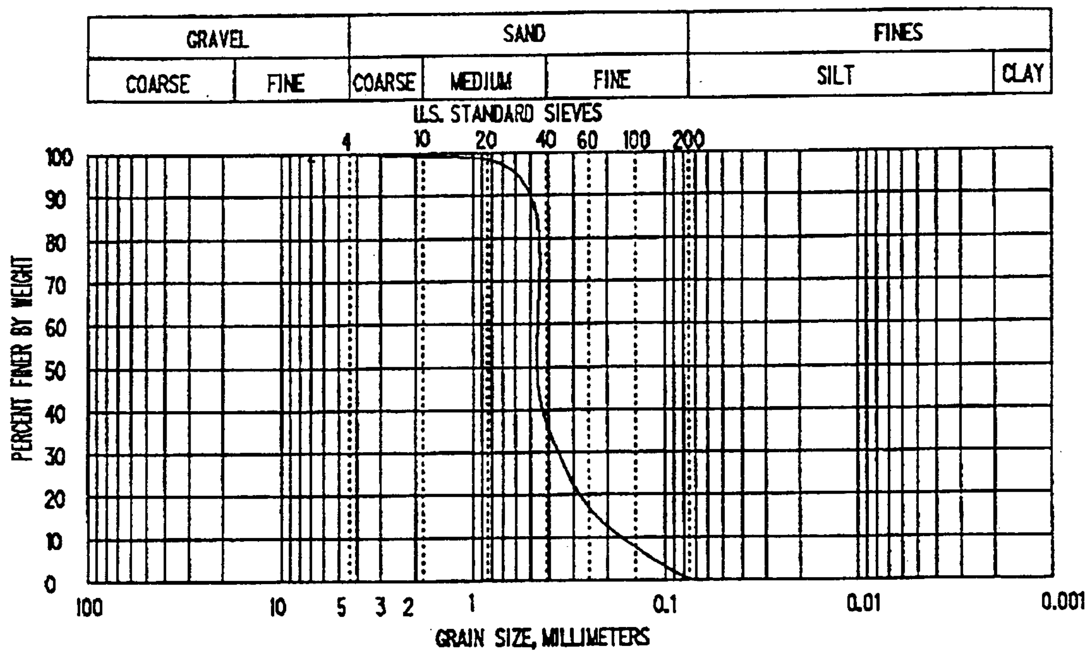
GRAIN SIZE CURVE

MECHANICAL SEIVE

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-8802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-2, S-17
PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



PERCENT PASSING: #4	100 %	SOIL DESCRIPTION:	SAND
#10	99.7	USCS CLASS:	SP
#40	34.1	SOIL ORIGIN:	COASTAL SEDIMENT
#60	17.0	SOIL COLOR:	TAN
#100	8.24	SPECIFIC GRAVITY:	
#200	0.5	MEDIAN SIZE (D50)	0.48 MM

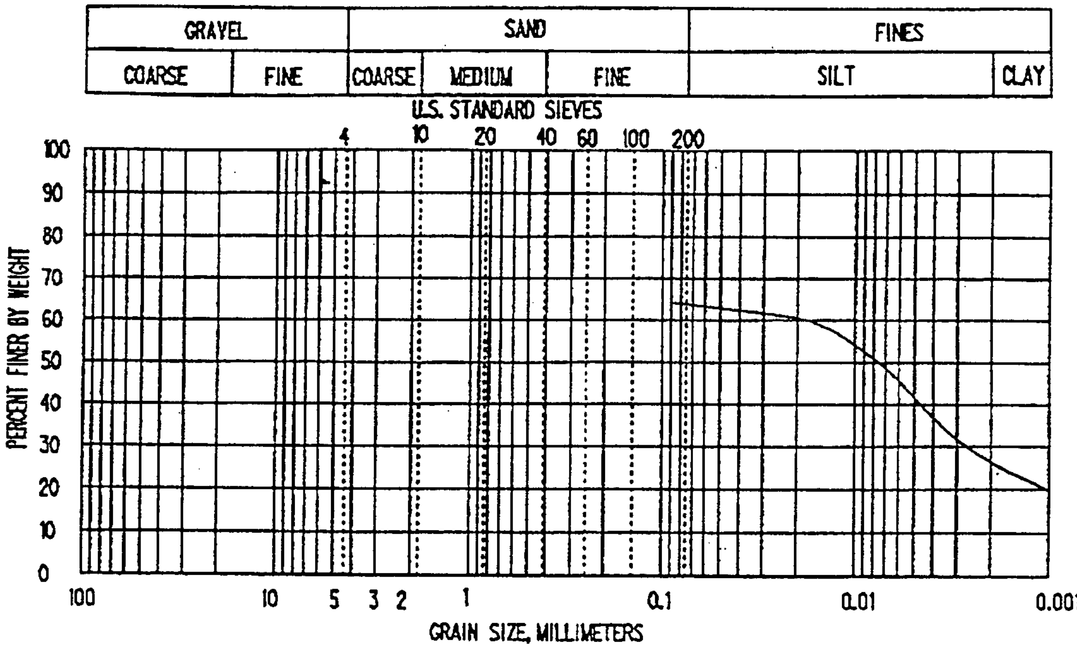
GRAIN SIZE CURVE

MECHANICAL SEIVE

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0803 FAX 908-6802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-3, S-1
PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



SOIL DESCRIPTION: CLAY-SANDY
USCS CLASS: CL
SOIL ORIGIN: COASTAL SEDIMENT
SOIL COLOR: RED-WHITE MOTTLED
SPECIFIC GRAVITY: 2.7
MEDIAN SIZE (D50) N/A

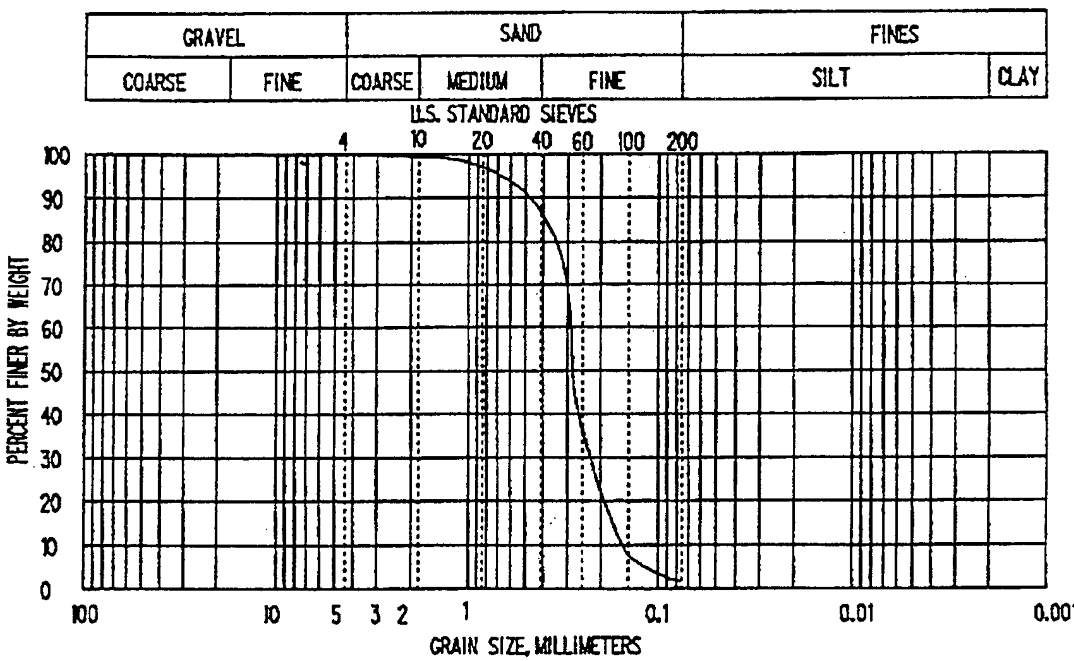
GRAIN SIZE CURVE

HYDROMETER ONLY

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1752 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-8802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-3, S-3
PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



PERCENT PASSING: #4	100 %	SOIL DESCRIPTION:	SAND-TRACE CLAY
#10	99.8	USCS CLASS:	SP
#40	87.1	SOIL ORIGIN:	COASTAL SEDIMENT
#60	37.2	SOIL COLOR:	RED-BROWN
#100	8.1	SPECIFIC GRAVITY:	
#200	2.7	MEDIAN SIZE (D50)	0.28 MM

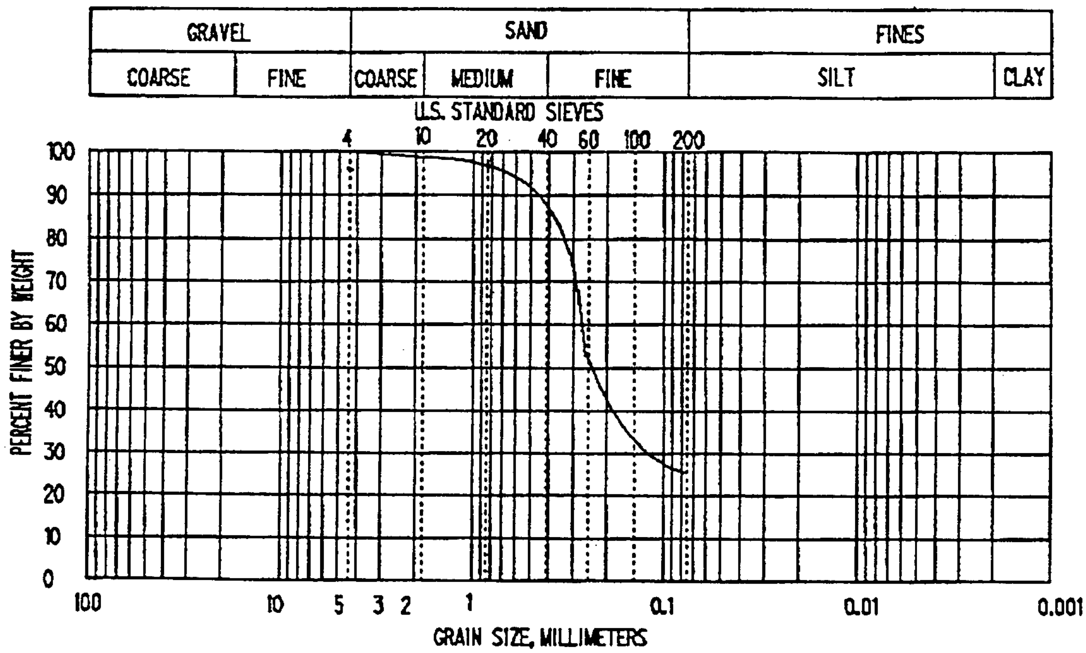
GRAIN SIZE CURVE

MECHANICAL SEIVE

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-8802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-3, S-7
PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



PERCENT PASSING: #4	99.8%	SOIL DESCRIPTION:	SAND-SOME. CLAY
#10	99.0	USCS CLASS:	SC
#40	89.7	SOIL ORIGIN:	COASTAL SEDIMENT
#60	52.1	SOIL COLOR:	TAN
#100	31.4	SPECIFIC GRAVITY:	
#200	26.7	MEDIAN SIZE (D50)	0.28 MM

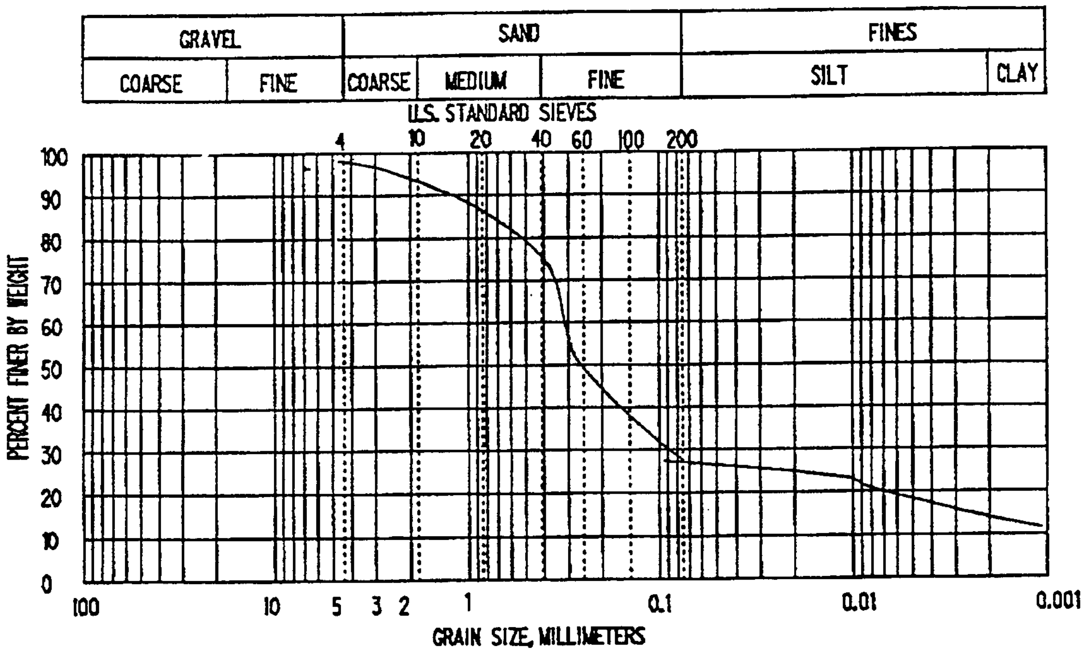
GRAIN SIZE CURVE

MECHANICAL SEIVE

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1796 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-6802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: R-3, S-11
PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



PERCENT PASSING:			
#4	98.5%	SOIL DESCRIPTION:	SAND-SOME CLAY
#10	94.1	USCS CLASS:	SC
#40	76.5	SOIL ORIGIN:	COASTAL SEDIMENT
#60	49.3	SOIL COLOR:	TAN
#100	37.4	SPECIFIC GRAVITY:	2.7
#200	27.7	MEDIAN SIZE (D50)	0.25 MM

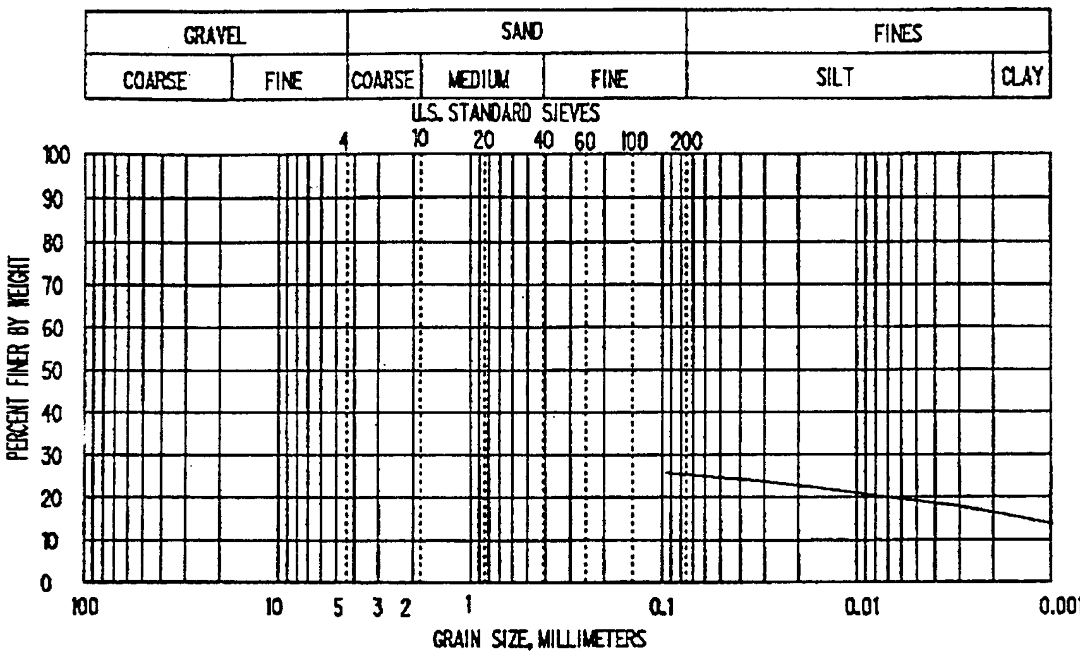
GRAIN SIZE CURVE

WITH HYDROMETER

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-8802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-3, S-15
PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



SOIL DESCRIPTION:	SAND-SOME CLAY
USCS CLASS:	SC
SOIL ORIGIN:	COASTAL SEDIMENT
SOIL COLOR:	WHITE-GREY
SPECIFIC GRAVITY:	2.9
MEDIAN SIZE (D50)	N/A

GRAIN SIZE CURVE

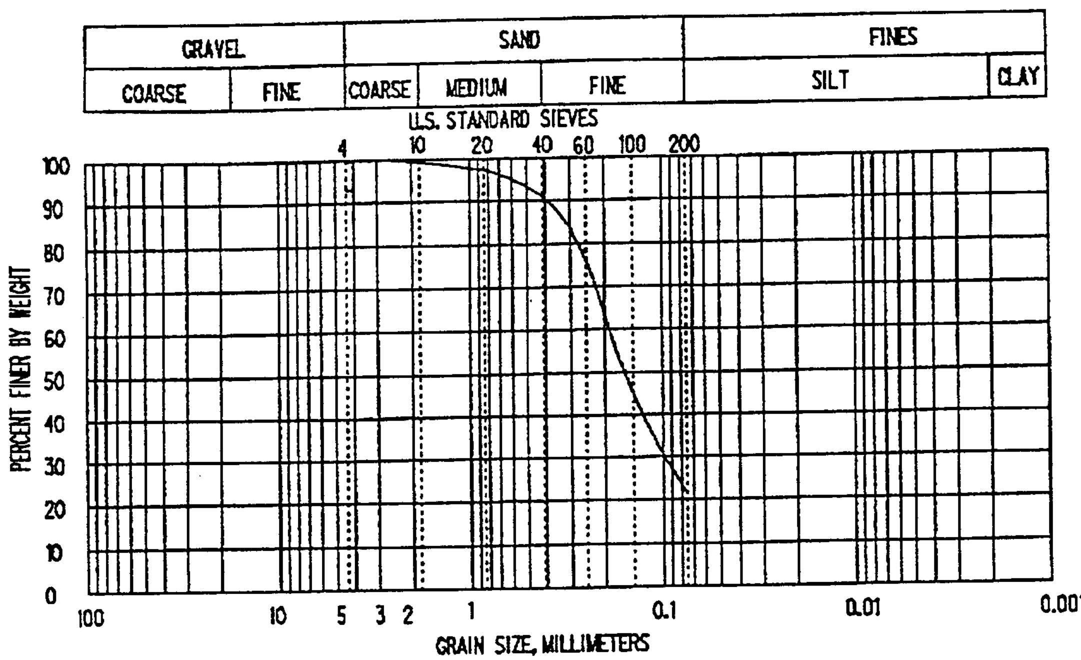
HYDROMETER ONLY

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-8802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-3, S-18

PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



PERCENT PASSING: #4	100 %	SOIL DESCRIPTION:	SAND-TRACE CLAY
#10	99.9	USCS CLASS:	SP
#40	90.3	SOIL ORIGIN:	COASTAL SEDIMENT
#60	75.4	SOIL COLOR:	RED-BROWN
#100	44.0	SPECIFIC GRAVITY:	
#200	22.4	MEDIAN SIZE (D50)	0.17 MM

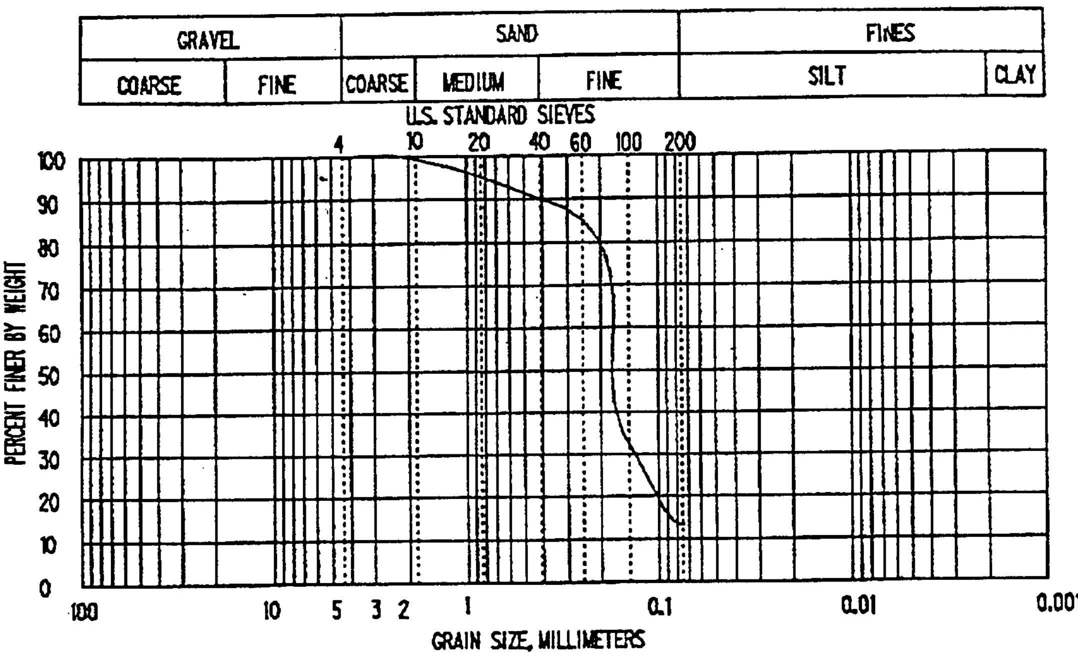
GRAIN SIZE CURVE

MECHANICAL SEIVE

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1758 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0808 FAX 908-8802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-4, S-7
PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



PERCENT PASSING: #4	100 %	SOIL DESCRIPTION:	SAND-SOME CLAY
#10	99.7	USCS CLASS:	SC
#40	90.3	SOIL ORIGIN:	COASTAL SEDIMENT
#60	86.2	SOIL COLOR:	WHITE-PINK
#100	30.3	SPECIFIC GRAVITY:	
#200	13.3	MEDIAN SIZE (D50)	0.16 MM

GRAIN SIZE CURVE

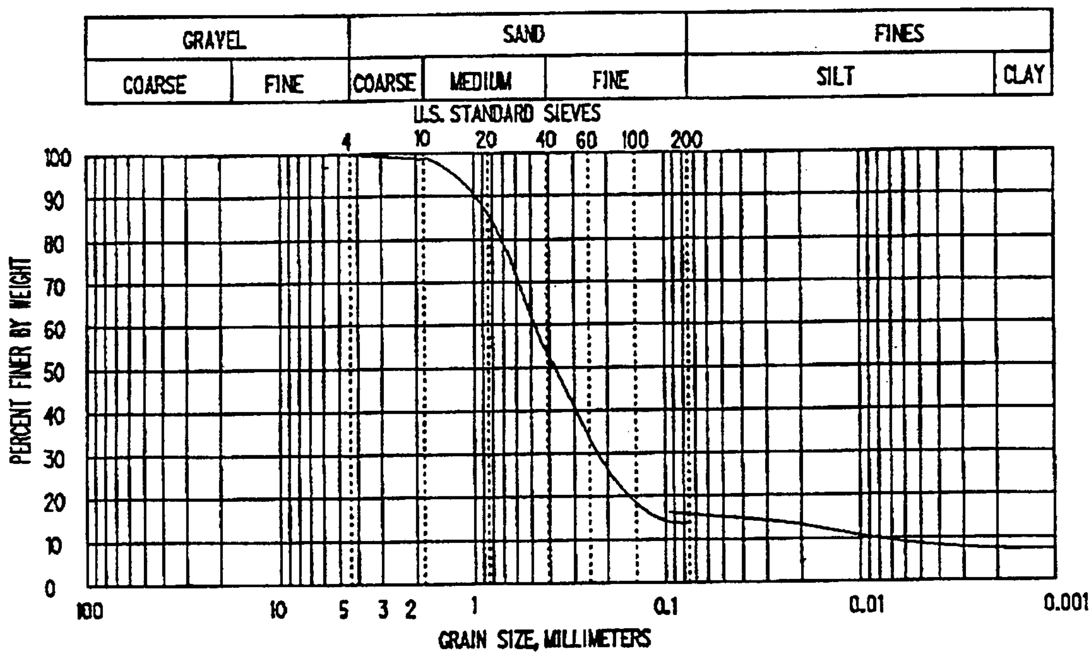
MECHANICAL SEIVE

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1798 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-6802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-4, S-10

PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



PERCENT PASSING: #4	99.9%	SOIL DESCRIPTION:	SAND-SOME CLAY
#10	99.5	USCS CLASS:	SC
#40	53.7	SOIL ORIGIN:	COASTAL SEDIMENT
#60	33.5	SOIL COLOR:	TAN-WHITE
#100	19.1	SPECIFIC GRAVITY:	2.75
#200	14.2	MEDIAN SIZE (D50)	0.002 MM

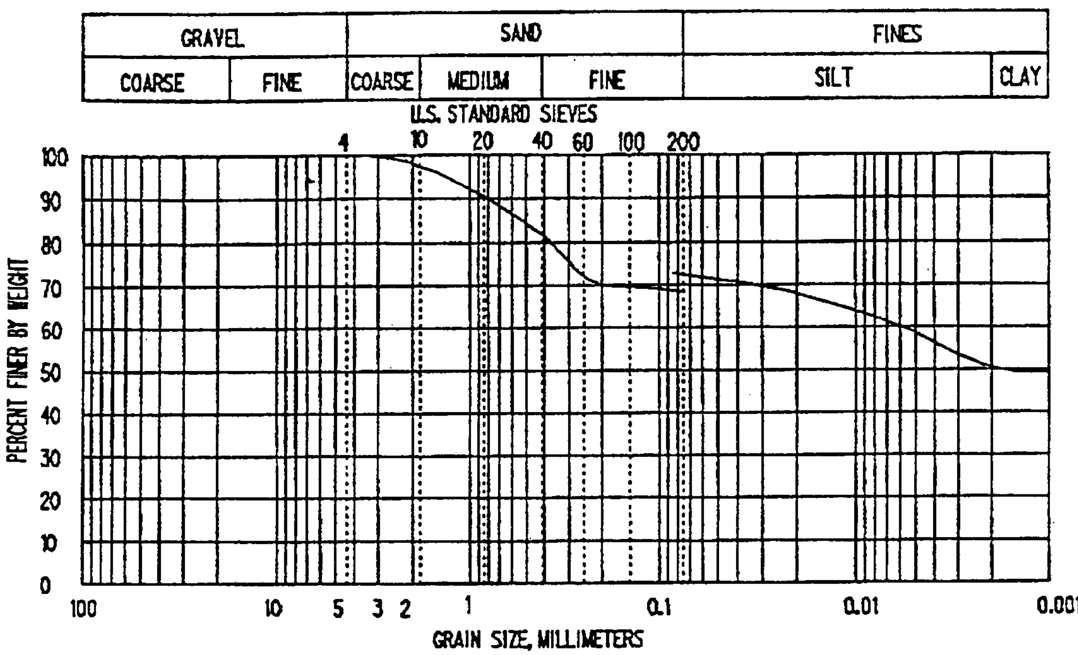
GRAIN SIZE CURVE

WITH HYDROMETER

LAB TECH: JERRY JOHNSON CHECKED BY: PIET DEPREE, P.E.

ADVANCED ENVIRONMENTAL MANAGEMENT, INC.
1758 MONTREAL CIRCLE, SUITE A
TUCKER, GEORGIA 30084
404 - 908-0809 FAX 908-8802

CONTRACTED WITH: U.S. ARMY CERL SAMPLE I.D.: B-4, S-13
PROJECT NAME: FT. BENNING LANDFARM JOB NO.: J00148 DATE: 6/20/94



PERCENT PASSING: #4 100 %
#10 98.2
#40 82.4
#60 72.5
#100 69.1
#200 67.7

SOIL DESCRIPTION: CLAY-SOME SAND
USCS CLASS: CL
SOIL ORIGIN: COASTAL SEDIMENT
SOIL COLOR: GREY-WHITE
SPECIFIC GRAVITY: 2.7
MEDIAN SIZE (D50) 0.002 MM

GRAIN SIZE CURVE

WITH HYDROMETER

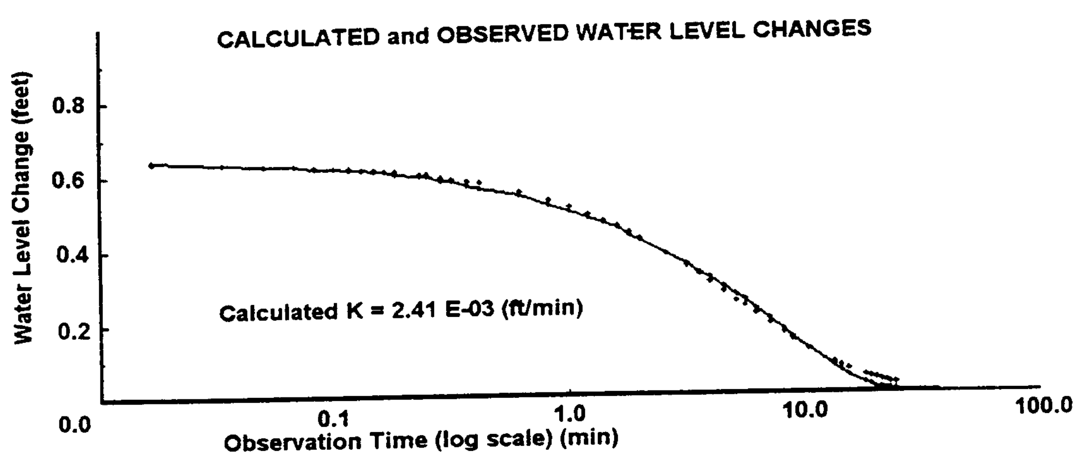
LAB TECH: JERRY JOHNSON

CHECKED BY: PIET DEPREE, P.E.

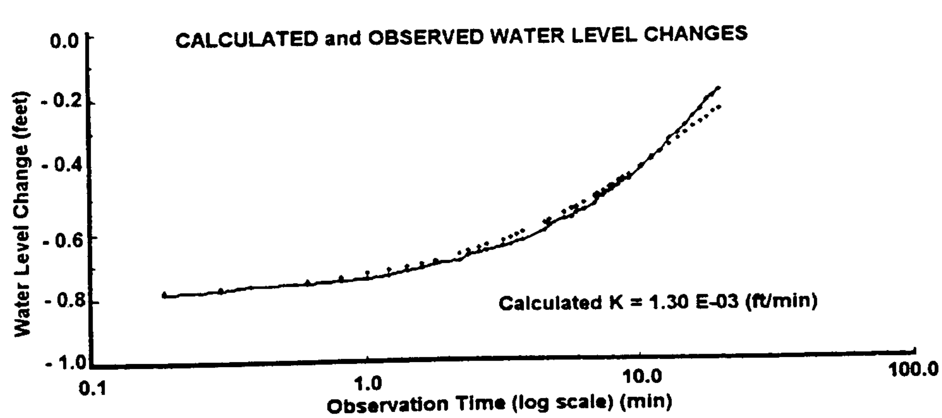
Appendix O: Hydraulic Conductivity Values

Hydraulic Conductivity Results Utilizing AQUITEST

Slug Test completed 6-17-94



Bail Test completed 6-17-94



Hydraulic Conductivity Results Utilizing Bouwer and Rice Method (1976)

$$K = \frac{r_c^2 \ln (R_e / r_w)}{2L} \frac{1}{t} \ln \frac{y_o}{y_t} \tag{5}$$

where: K = hydraulic conductivity of the aquifer (ft/min)
r_c = inside radius of the casing = 0.167 ft
R_e = effective radius over which y is dissipated
r_w = radial distance between the undisturbed aquifer and the well center = 0.167 ft
L = height of the screen in the well = 5 ft
y = drawdown at time *t* (ft)

and:

$$\ln \frac{R_e}{r_w} = \left[\frac{1.1}{\ln (H/r_w)} + \frac{A + B \ln [(D-H)/r_w]}{L/r_w} \right]^{-1} \tag{6}$$

where: $[(D - H)/r_w] = 6$
and constants A and B = 2.5 and 0.75, respectively.

Resulting Values for Hydraulic Conductivity of the Watertable Aquifer at the Site

Well Tests	Hydraulic Conductivity (ft/min)
Slug Test (AQUITEST)	2.4×10^{-3}
Bail Test (AQUITEST)	1.3×10^{-3}
Slug Test (Bouwer and Rice)	1.4×10^{-4}
Bail Test (Bouwer and Rice)	5.7×10^{-5}
Lab Test	3.5×10^{-4}

Appendix P: SCS Method of Abstractions

I. Determination of Soil Group

The hydrologic soil groups as defined by SCS soil scientists are:

A. (Low run-off potential). Soils having a high infiltration rate even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels.

B. Soils having a moderate infiltration rate when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse texture.

C. Soils having a slow infiltration rate when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water or soils with moderately fine to fine texture.

D. (High run-off potential). Soils having a very slow infiltration rate when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high watertable, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material.

Hydraulic group B and a normal antecedent moisture climate (II) was selected as the best fit for overall characteristic of soil at the study area.

II. Determination of SCS Curve Number for Harps Creek watershed:

Land Use Description	Runoff Curve #	% of Site
Water surface of rivers and streams	100	28.7%
Wood or forest land: thin stand, poor cover, no mulch	66	15.0%
Wood or forest land: good cover	55	41.3%
Open Spaces, good condition: grass cover on 75% or more of the area	61	15.0%

Weighted CN Number = (0.287)(100) + (0.15)(66) + (0.413)(55) + (0.15)(61) = 70.47

SCS Method of Abstractions Equations:

$$S = \frac{1000}{CN} - 10 \tag{7}$$

$$Pe = \frac{(P - 0.2S)^2}{P + 0.8S} \tag{8}$$

where: S = SCS Curve Number
P = Precipitation
Pe = Direct Runoff

SCS Curve Number for AMC (II) = (1000/70.47) - 10 = 4.19
Run-off for 48.8 inches of average rainfall = $[48.8 - 0.02\ (4.19)]^2 / [48.8 + 0.8\ (4.19)] = 44.80$ in
Infiltration = 48.8 - 44.80 = 4.0 in/yr = 6×10^{-7} ft/min

(Source: SCS, 1972, National Engineering Handbook, Section 4, Hydrology: Washington D.C., U.S. Government Printing Office.)

Appendix Q: Statistical Rainfall Intensity Data for Fort Benning

Return Periods	30-Min Rain (in)	30-Min Rate (in/hr)	60-Min Rain (in)	60-Min Rate (in/hr)	2-Hour Rain (in)	2-Hour Rain (in/hr)
1-yr	1.35	2.70	1.72	1.72	2.06	1.03
2-yr	1.56	3.12	1.96	1.96	2.37	1.19
5-yr	1.90	3.80	2.44	2.44	2.94	1.47
10-yr	2.14	4.28	2.72	2.72	3.39	1.70
25-yr	2.40	4.80	3.05	3.05	3.85	1.93
50-yr	2.69	5.38	3.35	3.35	4.25	2.13
100-yr	2.90	5.80	3.72	3.72	4.73	2.37

Return Periods	3-Hour Rain (in)	3-Hour Rate (in/hr)	6-Hour Rain (in)	6-Hour Rate (in/hr)
1-yr	2.19	0.73	2.63	0.44
2-yr	2.62	0.87	2.98	0.50
5-yr	3.29	1.10	3.92	0.65
10-yr	3.73	1.24	4.47	0.75
25-yr	4.27	1.42	5.11	0.85
50-yr	4.71	1.57	5.77	0.96
100-yr	5.23	1.74	6.41	1.07

Return Periods	12-Hour Rain (in)	12-Hour Rate (in/hr)	24-Hour Rain (in)	24-Hour Rate (in/hr)
1-yr	3.00	0.25	3.47	0.15
2-yr	3.71	0.31	4.00	0.17
5-yr	4.60	0.38	5.40	0.23
10-yr	5.36	0.45	6.35	0.27
25-yr	6.17	0.51	7.36	0.31
50-yr	6.89	0.57	7.96	0.33
100-yr	7.68	0.64	8.87	0.37

Source: Hershfield 1961

Appendix R: SCS Rainfall Distribution for 24-Hour Storm

I. Calculation of rainfall distribution of a 24-hr/100-yr storm event in a Type II storm area based on 8.87 total inches of precipitation or an intensity of 0.37 inches/hour (Hershfield 1961).

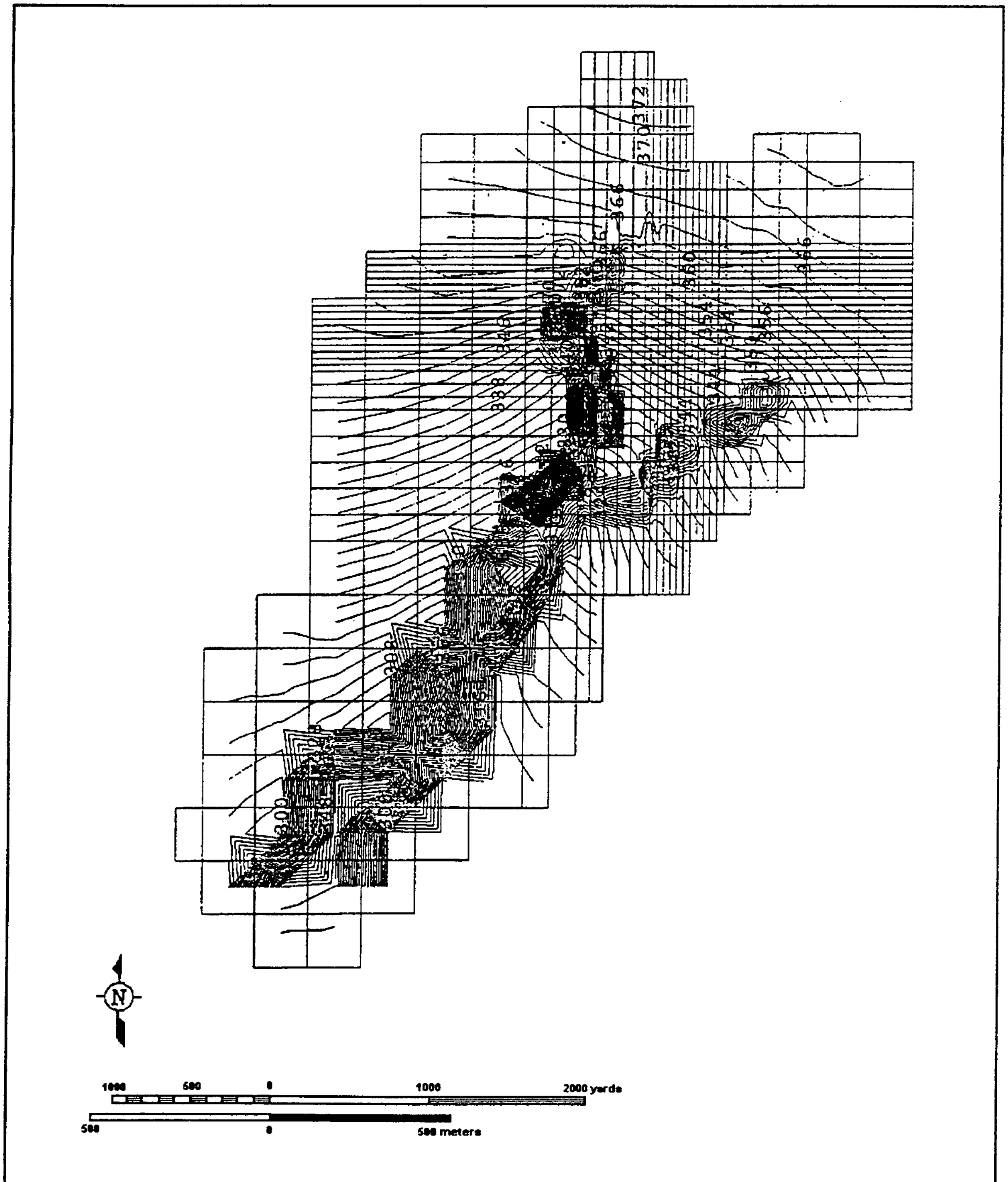
Hour t	P_t / P_{24}	Increment	Precipitation (in)
2	0.022	0.022	0.1951
4	0.048	0.026	0.2306
6	0.08	0.032	0.2838
7	0.098	0.018	0.1597
8	0.12	0.022	0.1951
8.5	0.133	0.013	0.1153
9	0.147	0.014	0.1242
9.5	0.163	0.016	0.1419
9.75	0.172	0.009	0.0798
10	0.181	0.009	0.0798
10.5	0.204	0.023	0.2040
11	0.235	0.031	0.2750
11.5	0.283	0.048	0.4258
11.75	0.357	0.074	0.6564
12	0.663	0.306	2.7142
12.5	0.735	0.072	0.6386
13	0.772	0.037	0.3282
13.5	0.799	0.027	0.2395
14	0.82	0.021	0.1863
16	0.88	0.06	0.5322
20	0.952	0.072	0.6386
24	1.000	0.048	0.4258
TOTALS		1.000	8.87

II. The resultant rates of recharge for transient simulation:

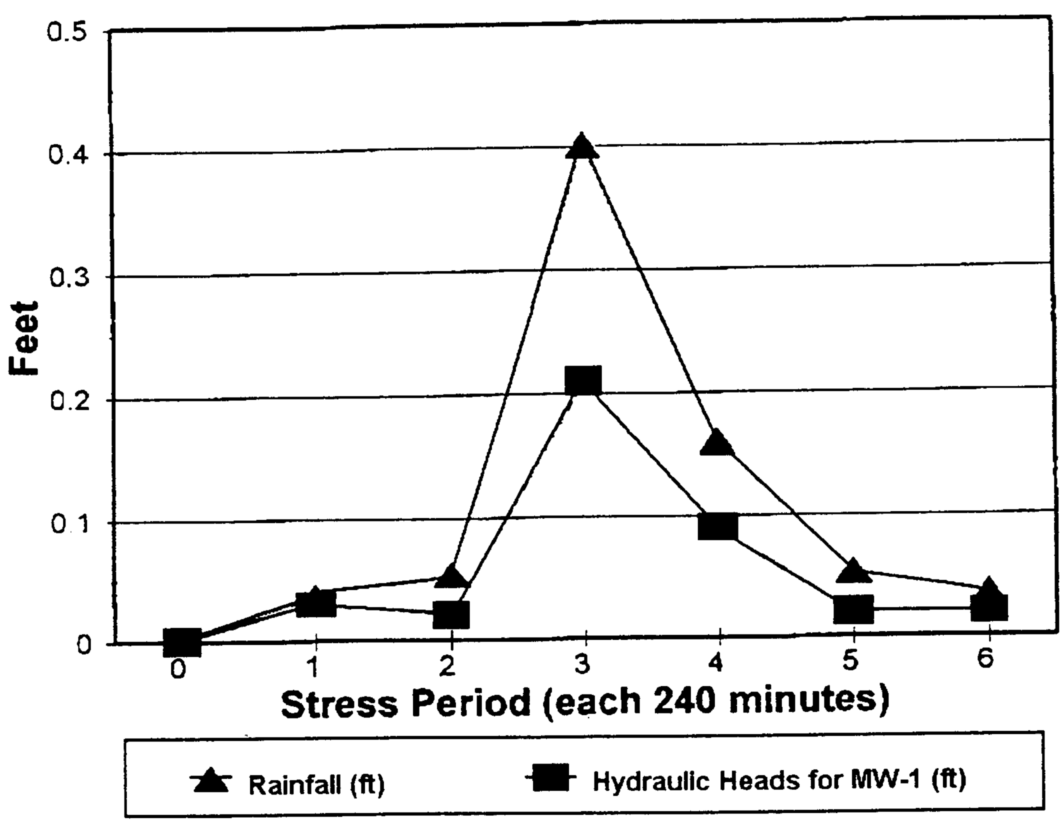
Stress Period (each 240 minutes)	Rate of Recharge (ft/min)	
	12% Recharge of Precipitation	100% Recharge of Precipitation
1	1.8×10^{-5}	1.48×10^{-4}
2	2.7×10^{-5}	2.22×10^{-4}
3	2.01×10^{-4}	1.67×10^{-3}
4	8.0×10^{-5}	6.68×10^{-3}
5	2.7×10^{-5}	2.22×10^{-4}
6	1.8×10^{-5}	1.48×10^{-4}

Appendix S: Transient Model Results

Typical Groundwater Flow For Watershed During 100-yr/24-hr Storm Event



Comparison of Typical Changes in Hydraulic Head and Rainfall
During a 100-yr/24-hr Storm Event



Appendix T: Logging Data

1995 Drilling Logs

CONTRACTED WITH: CORPS OF ENGINEERS BORING NO.: MW-2

PROJECT NAME: FT. BENNING LAND FARM JOB NO.: 951349-01-05 DATE: 10/24/95

DRILLER: KILMAN BROTHERS RIG: TRUCK LOGGED BY: WKC

ELEV.	DESCRIPTION	DEPTH IN FEET	SAMPLES NO.	TYPE	BLOWS/6'	RECOV.	NOTES
		0					
	SAND-SILTY; TRACE MICA; HARD; LIGHT RED-ORANGE (RESIDUAL)		1	/	8-12-20	20"	
	-BANDED: WHITE-ORANGE; MEDIUM DENSE	5	2	/	10-10-10	19"	
	-TRACE SILT; MEDIUM DENSE; RED	10	3	/	14-11-14	22"	
	-DENSE; DEEP RD/BURGUNDY	15	4	/	13-13-23	20"	
	-DENSE; LIGHT ORANGE	20	5	/	14-17-24	23"	
	-DENSE; YELLOW-LIGHT ORANGE	25	6	/	9-11-21	15"	
	-DENSE; DARK YELLOW-LIGHT ORANGE	30	7	/	15-17-31	16"	
	-MEDIUM DENSE; RED-DARK RED	35	8	/	10-12-14	14"	POSSIBLE SHALLOW CLAY LAYER 36 AND 39 FT.
	-SOME SILT; TRACE CLAY; FIRM; BANDED: WHITE-RED-YELLOW	40	9	/	8-7-10	18"	
	-TRACE CLAY; DENSE; BANDED: YELLOW-ORANGE	45	10	/	14-11-20	21"	
	-SOME SILT; TRACE CLAY; FIRM; BROWN, MOTTLED: DEEP YELLOW-RED	50	11		13-6-8	19"	

1995 Drilling Logs

CONTRACTED WITH: CORPS OF ENGINEERS BORING NO.: MW-2

PROJECT NAME: FT. BENNING LAND FARM JOB NO.: 951349-01-05 DATE: 10/24/95

DRILLER: KILMAN BROTHERS RIG: TRUCK LOGGED BY: WKC

ELEV.	DESCRIPTION	DEPTH IN FEET	SAMPLES NO.	TYPE	BLOWS/6"	RECOV.	NOTES
		0					
	CLAY-TRACE SILT; STIFF; GRAY-YELLOW (RESIDUAL)	55	12	/	5-3-8	23"	SAND ABOVE + OR - CLAY LAYER IN SAND SAMPLE BELOW
	-SOME SAND; MEDIUM DENSE; GRAY-YELLOW-RED	60	13	/	8-16-18	24"	
	-SANDY; DENSE; YELLOW-WHITE		14	/	7-8-9	22"	
	SAND-SOME CLAY; FIRM; GRAY-YELLOW	65					SOME MAGNESE NODULES
	CLAY-SOME SAND; HARD; BROWN	70	15	/	6-18-14	24"	
	-SANDY; TRACE CLAY; VERY STIFF		16	/	9-12-13	22	
	SAND-COARSE; SOME CLAY; MEDIUM DENSE; YELLOW-WHITE-RED	75					
	-SOME SILT; TRACE CLAY; YELLOW	80	17	/			DROPPED SPOON IN BORE HOLE
	-MEDIUM DENSE; MOIST; YELLOW	85	18	/	8-8-15	18"	
	-SILTY; LOOSE; MOIST; BANDED: YELLOW-RED	90	19	/	2-2-3	20"	
	BORING TERMINATED AT 94 FEET	95				100%	

☒ UNDISTURBED SAMPLE

GROUNDWATER ENCOUNTERED AT 83.5 FT. AT TIME OF BORING

1995 Drilling Logs

CONTRACTED WITH: CORPS OF ENGINEERS BORING NO.: MW-3

PROJECT NAME: FT. BENNING LAND FARM JOB NO.: 951349-01-05 DATE: 10/23/95

DRILLER: KILMAN BROTHERS RIG: TRUCK LOGGED BY: WKC

ELEV.	DESCRIPTION	DEPTH IN FEET	SAMPLES NO.	TYPE	BLOWS/6"	RECOV.	NOTES
		0					
	SAND-LOOSE; RED-BROWN (RESIDUAL)		1	/	5-3-3	20"	
	-SOME CLAY; LOOSE; TAN-ORANGE	5	2	/	5-3-4	22"	
	-SOME CLAY; FIRM; BANDED: ORANGE-GRAY	10	3	/	4-6-8	16"	
	-MEDIUM DENSE; ORANGE	15	4	/	7-11-15	20"	
	-DENSE; LIGHT ORANGE	20	5	/	8-12-21	21"	
	-MEDIUM DENSE; YELLOW-WHITE	25	6	/	8-11-16	18"	
	-TRACE SILT; MEDIUM DENSE; MOIST; RED- LIGHT BROWN	30	7	/	6-10-13	20"	
	SILT-SOME CLAY; TRACE MICA; LOOSE; GRAY-YELLOW-RED-ORANGE	35	8	/	1-3-5	21"	
	SAND-VERY DENSE; WHITE-TAN	40	9	/	13-26-27	17"	
	-SOME CLAY; FIRM; YELLOW-WHITE	45	10	/	3-5-6	19"	

1995 Drilling Logs

CONTRACTED WITH: CORPS OF ENGINEERS BORING NO.: MW-3

PROJECT NAME: FT. BENNING LAND FARM JOB NO.: 951349-01-05 DATE: 10/24/95

DRILLER: KILMAN BROTHERS RIG: TRUCK LOGGED BY: WKC

ELEV.	DESCRIPTION	DEPTH IN FEET	SAMPLES NO.	TYPE	BLOWS/6"	RECOV.	NOTES
		0					
	-SILTY; SOME CLAY; LOOSE; ORANG-	50	11	/	3-3-3	24"	
	-DENSE; BANDED: YELLOW-LIGHT BROWN-RED; MOTTLED: GRAY	55	12	/	9-13-17	20"	
	-SOME CLAY; MEDIUM DENSE; BANDED: YELLOW-DARK RED	60	13	/	4-9-13	24"	
	CLAY-SOME SAND; STIFF; WET; TAN-YELLOW	65	14	/	2-3-12	24"	
		70					
	BORING TERMINATED AT 74 FEET	75				60%	⊠ UNDISTURBED SAMPLE GROUNDWATER ENCOUNTERED AT 64.3 FT. AT TIME OF BORING

1995 Drilling Logs

CONTRACTED WITH: CORPS OF ENGINEERS BORING NO.: MW-4

PROJECT NAME: FT. BENNING LAND FARM JOB NO.: 951349-01-05 DATE: 10/25/95

DRILLER: KILMAN BROTHERS RIG: TRUCK LOGGED BY: WKC

ELEV.	DESCRIPTION	DEPTH IN FEET	SAMPLES NO.	TYPE	BLOWS/6'	RECOV.	NOTES
	TOPSOIL 6-IN.	0					
	SAND-SILTY; SOME CLAY; LOOSE; ORANGE-BROWN (RESIDUAL)		1		3-3-3	22'	
	-SOME SILT; FIRM; MOTTLED: ORANGE-ORANGE-YELLOW	5	2		3-5-7	16'	
	-TRACE CLAY; FIRM; ORANGE-YELLOW	10	3		5-7-7	20'	
	-TRACE CLAY; LOOSE; BANDED: DARK ORANGE-RED-WHITE-YELLOW	15	4		3-4-5	22'	
	-TRACE CLAY; FIRM; MOTTLED: DARK RED-ORANISH	20	5		9-7-6	18'	
	-LOOSE TO FIRM; YELLOW-ORANGE	25	6		3-5-5	20"	
	-COARSE; LOOSE; BANDED: ORANGE-YELLOW-BURGUNDY	30	7		8-5-5	20"	
	-COARSE; FIRM; BANDED: WHITE-YELLOW-RED	35	8		10-6-5	20"	
	-SOME CLAY; FIRM; YELLOW-GRAY	40	9		6-4-4	22'	SAND IN FIRST 12 IN. OF SAMPLE
	-COARSE; LOOSE; ORANGE-RED	45	10		7-5-5	22"	
	-COARSE; SOME CLAY; LOOSE; ORANGE-RED	50	11		8-5-4	20'	

1995 Drilling Logs

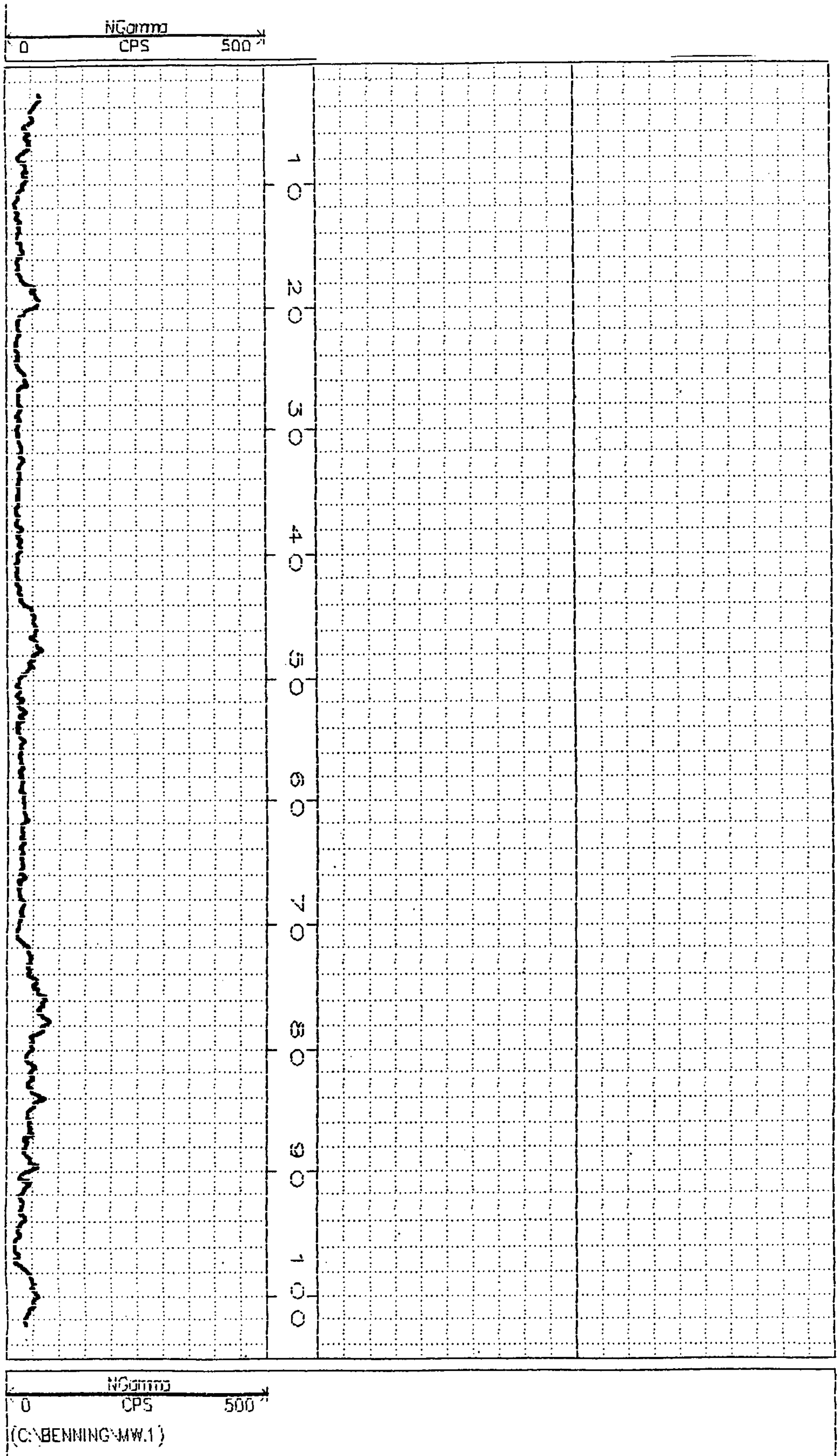
CONTRACTED WITH: CORPS OF ENGINEERS BORING NO.: MW-4

PROJECT NAME: FT. BENNING LAND FARM JOB NO.: 951349-01-05 DATE: 10/24/95

DRILLER: KILMAN BROTHERS RIG: TRUCK LOGGED BY: WKC

ELEV.	DESCRIPTION	DEPTH IN FEET	SAMPLES NO.	TYPE	BLOWS/6'	RECOV.	NOTES
		0					
	-COARSE; FIRM; WHITE-YELLOW	55	12		5-6-7	18'	
	-COARSE; LOOSE; WHITE-YELLOW	60	13		2-3-3	18'	6 IN. SANDY CLAY LAYER IN MIDDLE OF SAMPLE.
	CLAY-SANDY; VERY STIFF						
	SAND-VERY COARSE; MEDIUM DENSE; WHITE-YELLOW	65	14		10-5-16	20"	MOIST SANDY CLAY IN TOP 10 IN. OF SAMPLE.
	-TRACE SILT; COARSE; MEDIUM DENSE; MOIST; ORANGE	70	15		10-12-12	22"	
	SILT-SANDY; STIFF; MOIST; YELLOW-WHITE	75	16		4-5-7	24'	
	-SANDY; STIFF; WET; BANDED: YELLOW-GRAY-ORANGE	80	17		6-6-7	18"	
	BORING TERMINATED AT 84 FEET	85					☒ UNDISTURBED SAMPLE GROUNWATER ENCOUNTERED AT 76 FT. AT TIME OF BORING

Logging Data



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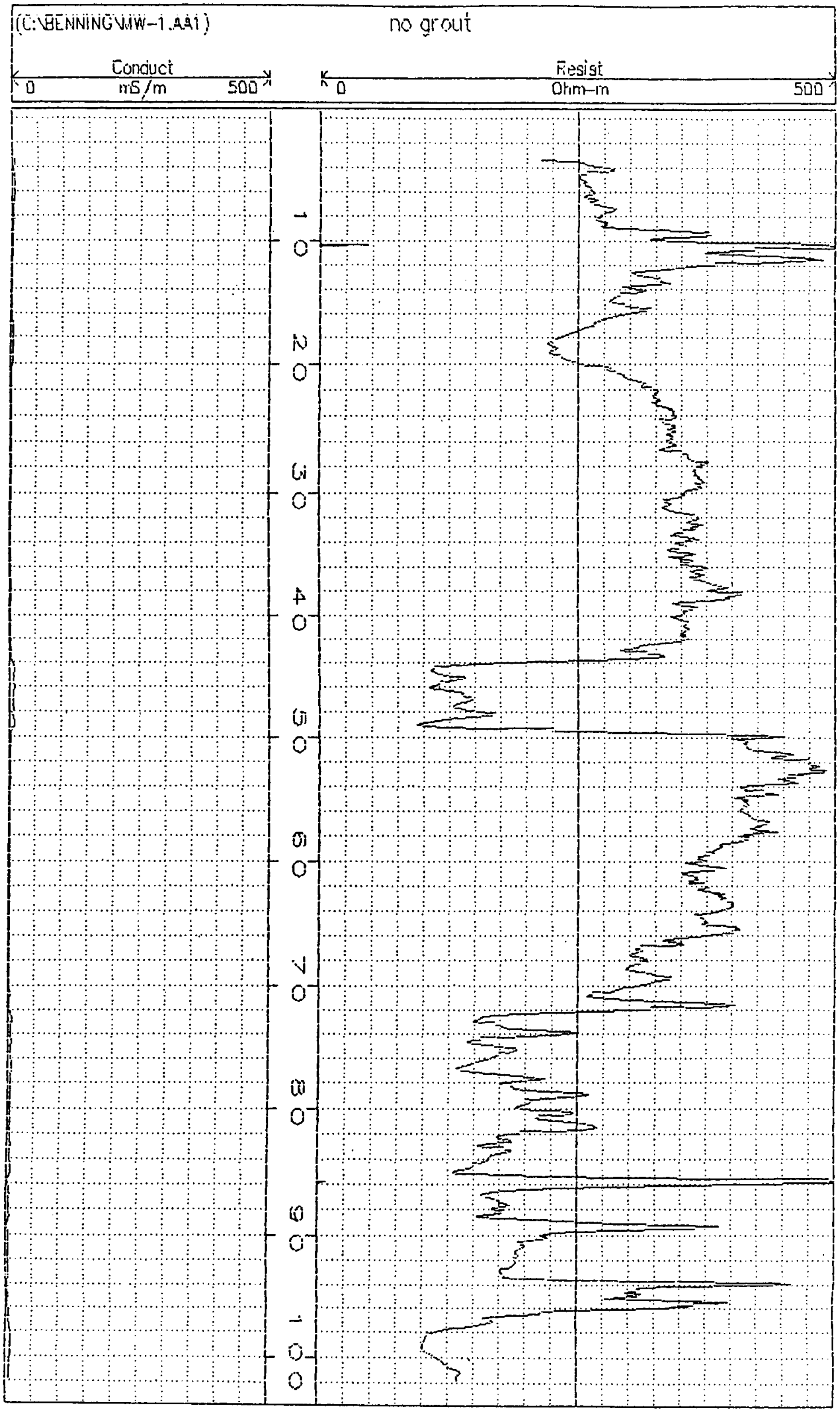

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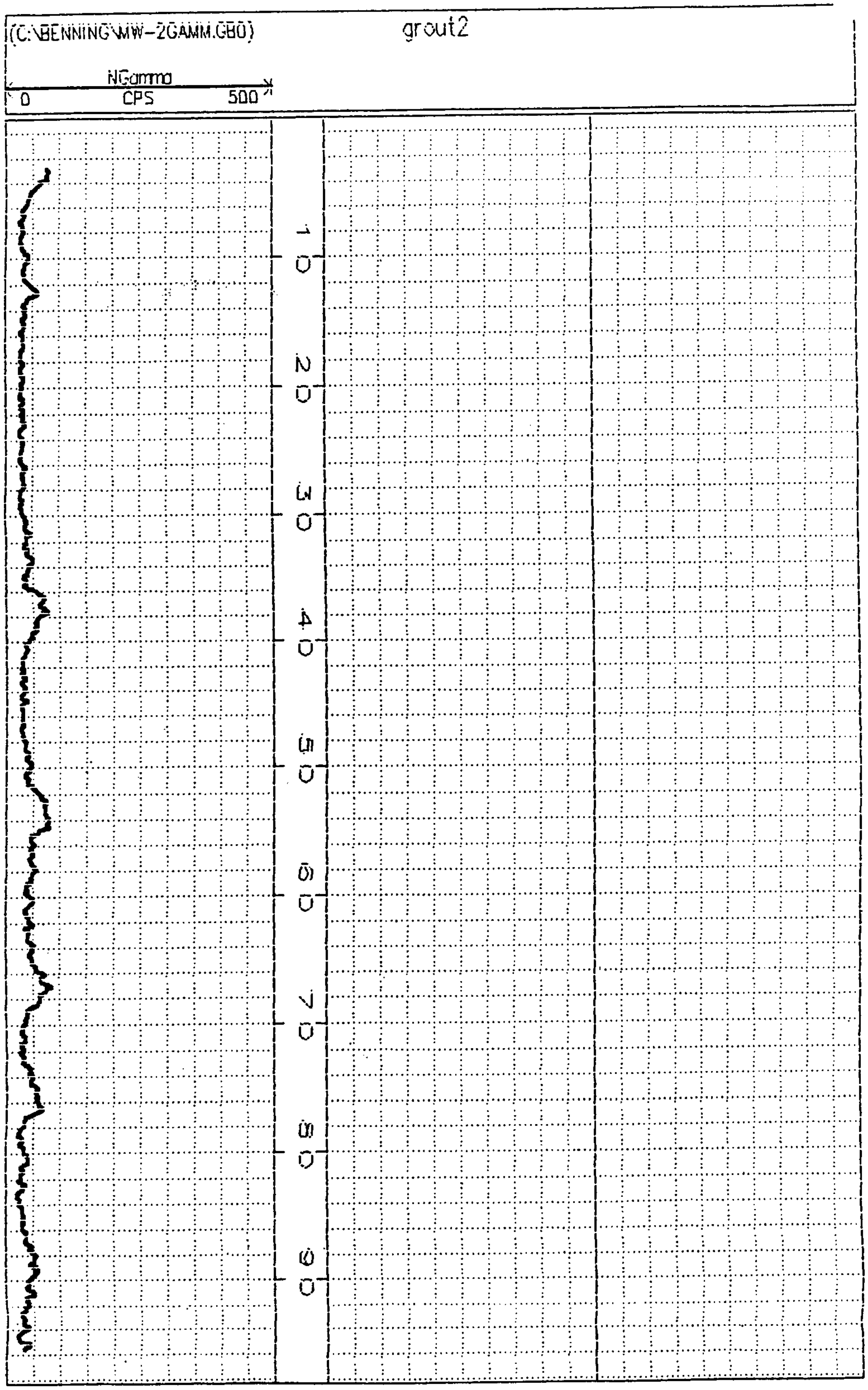

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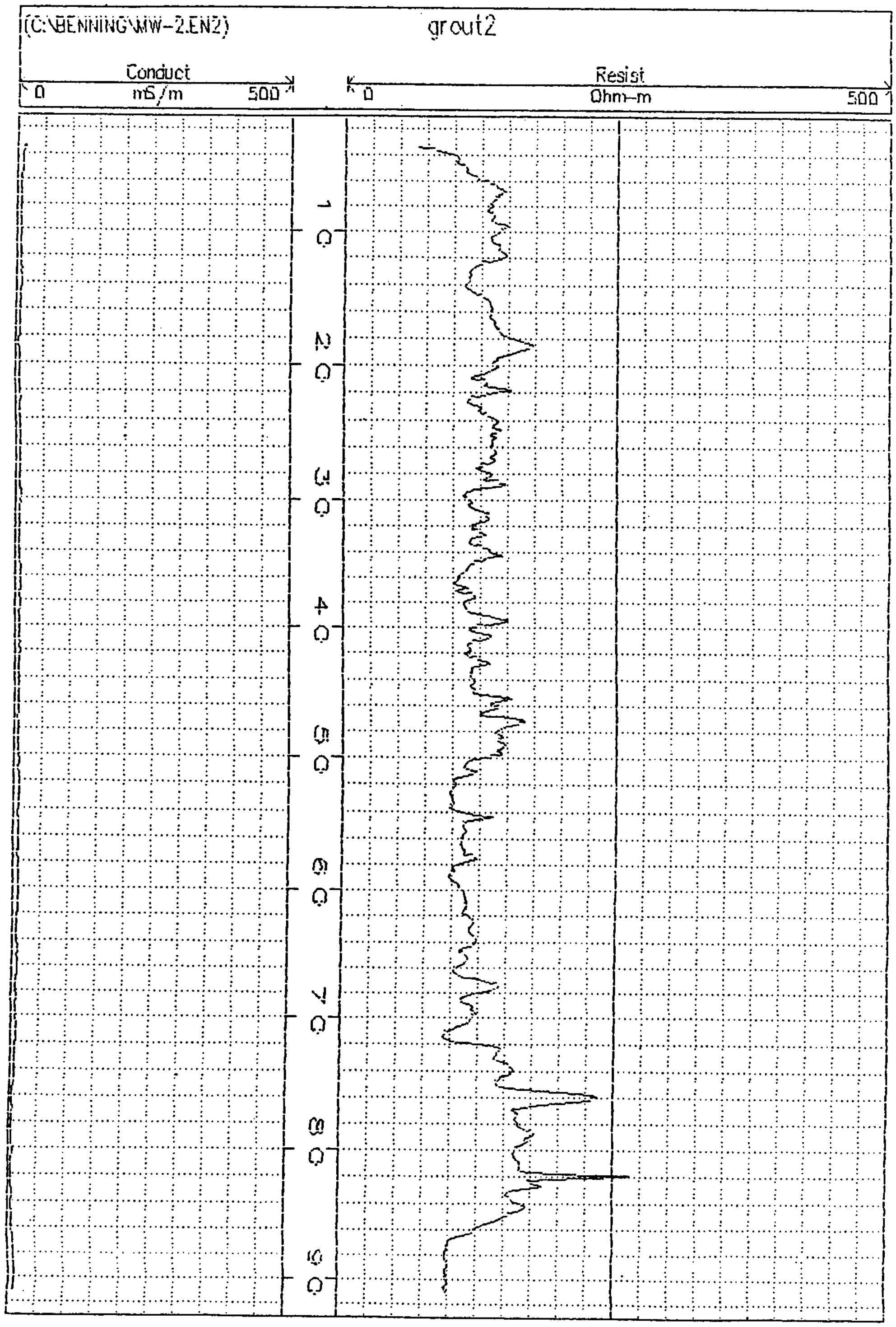

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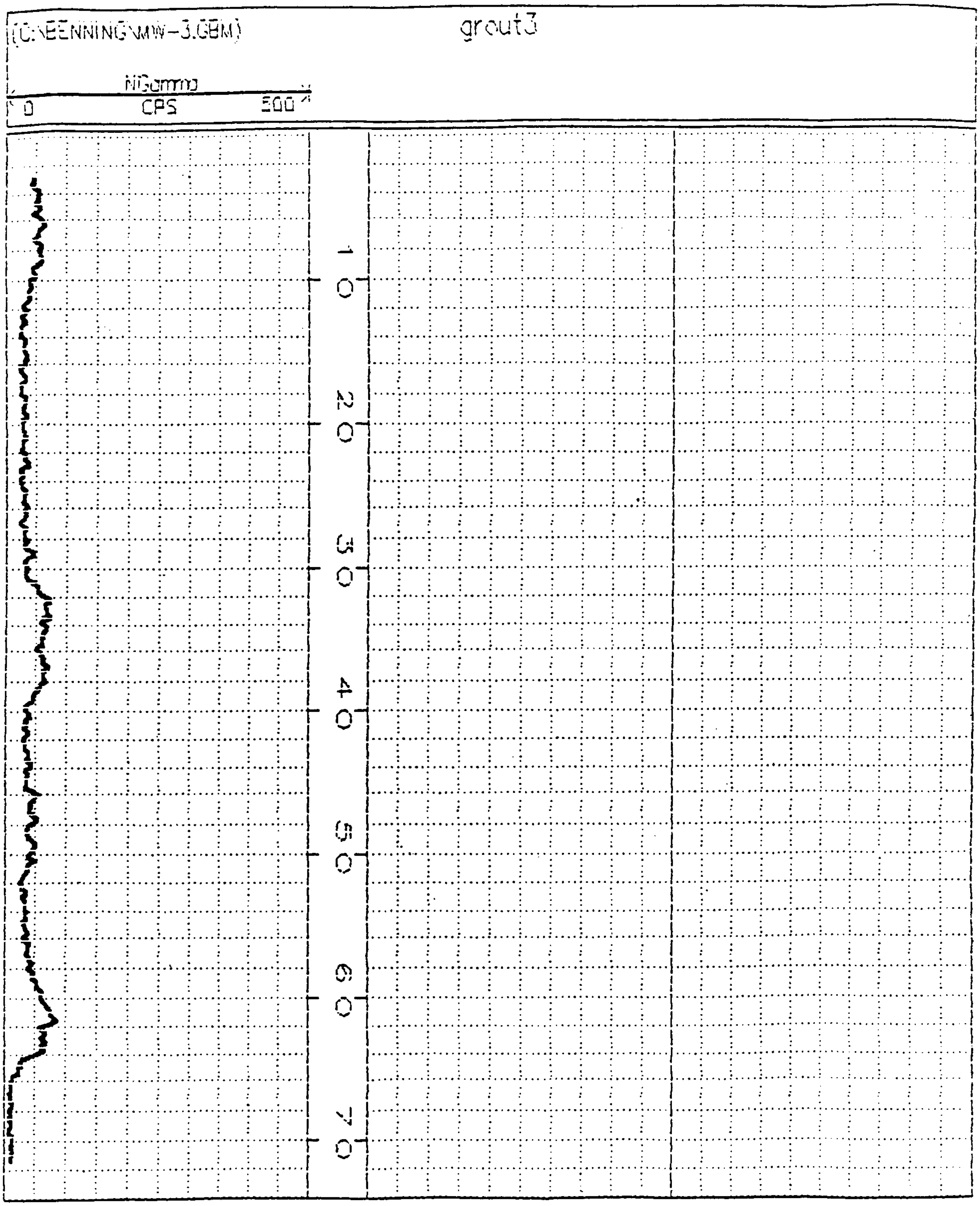

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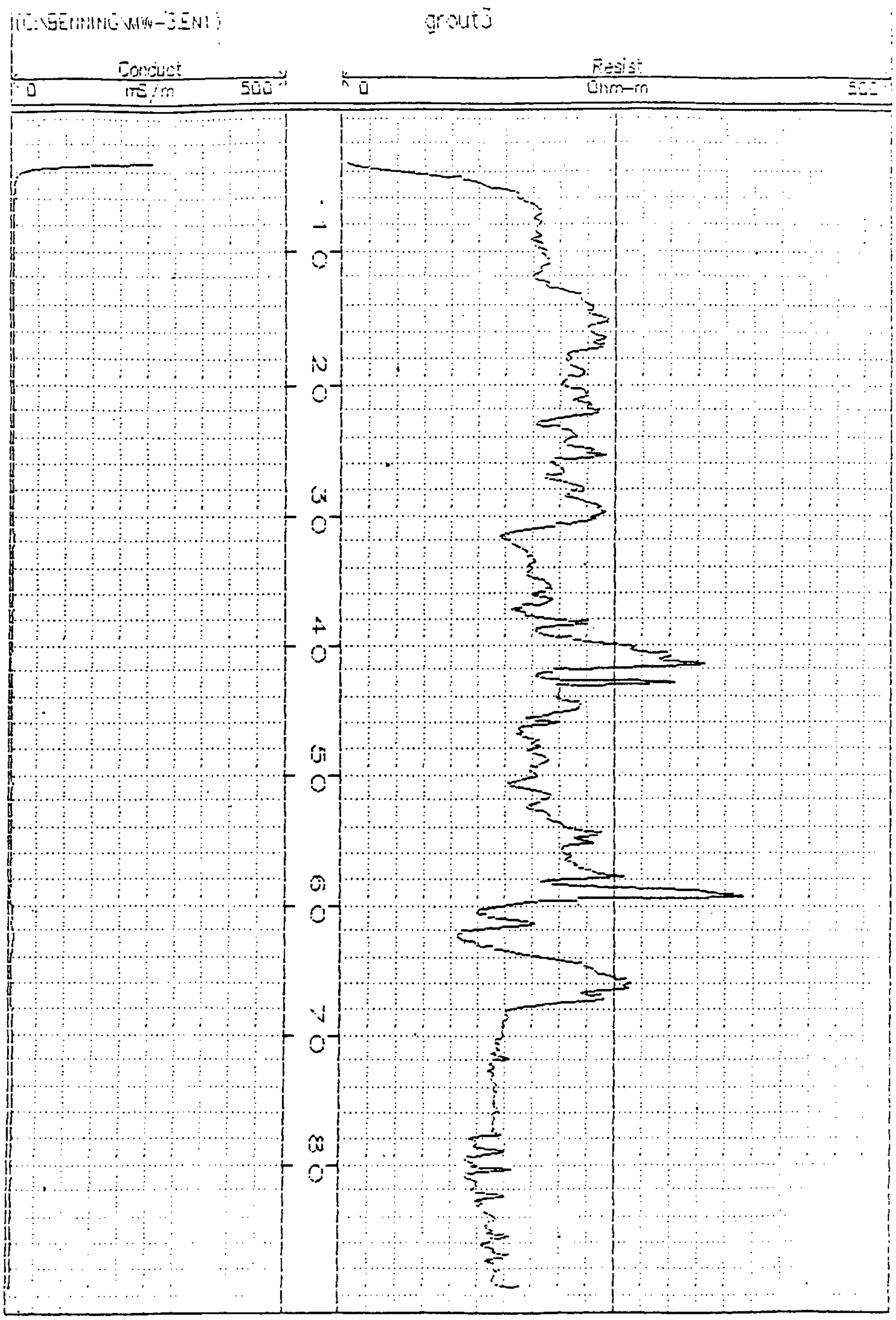

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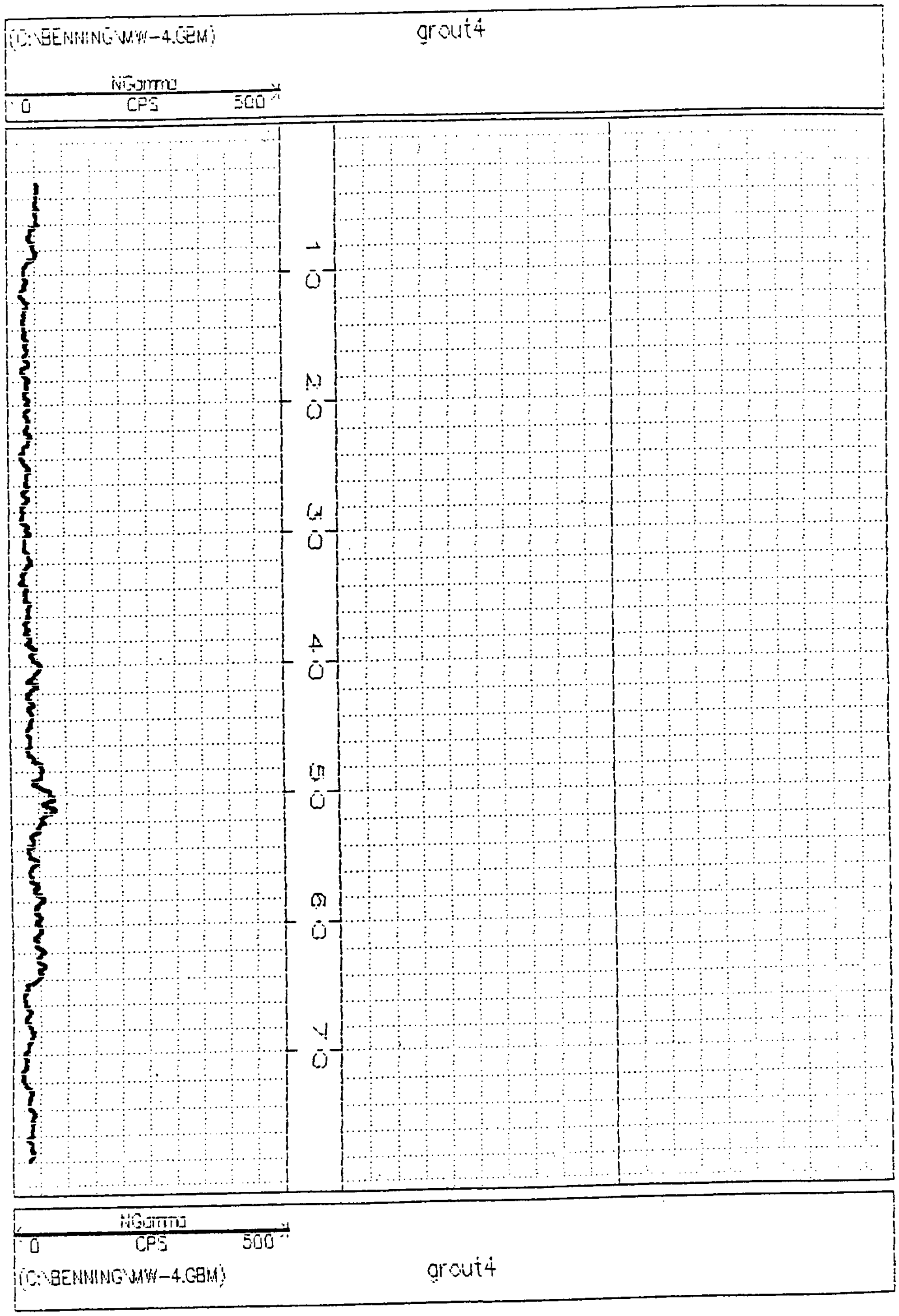

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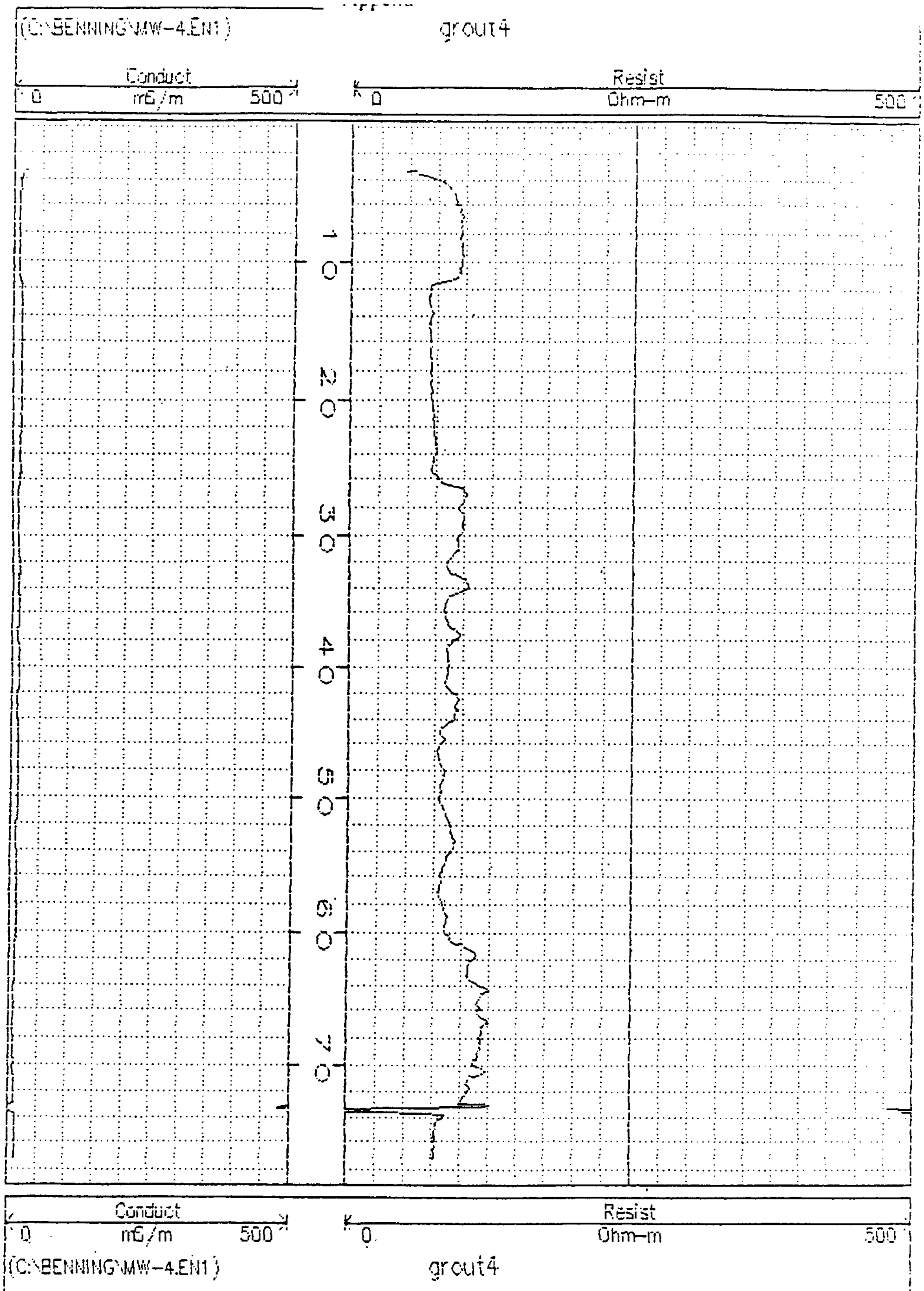


Logging Data

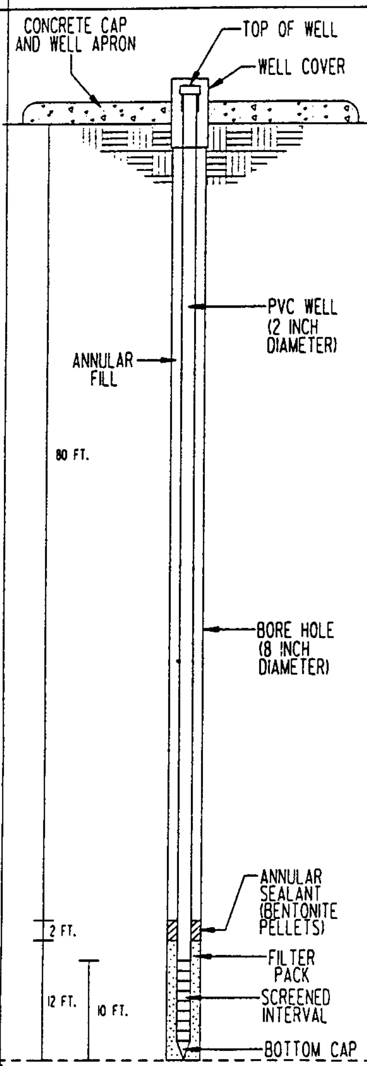
UNITED CONSULTING GROUP, LTD.
808 PARK NORTH BOULEVARD, SUITE 00
CLARKSTON, GEORGIA 3002?
404 - 296-988 FAX 296-676

WELL/PIEZOMETER LOG

SHEET 1 OF 1

CLIENT: ARMY CORPS OF ENGINEERS		DATE	TIME	WELL NO.:	MW-2
PROJECT NAME: FORT BENNING LANDFARM	STARTED:	10-24-95	9:00	WELL NO.:	WESTERN PORTION OF SITE
PROJECT NUMBER: 951349-01-05	COMPLETED:	10-26-95	12:00	ELEVATION (G.S.):	436.75
DRILLED BY: KILMAN BROTHERS				ELEVATION (T.O.P.):	439.64
LOGGED BY: KENT CAMPBELL					

ELEV. / DEPTH	DESCRIPTION	SKETCH	NOTES
0	ELEV. 436.75		RISER HEIGHT FROM G.S.: 2.9 FEET
			SIZE/THICKNESS OF APRON: 4 FOOT X 4 FOOT
			ANNULAR FILL: CEMENT GROUT
10			FILTER: 12 FEET SAND
			TOP OF SCREEN: 84 FEET
20			SCREEN LENGTH: 10 FEET
			SCREEN SLOT SIZE: 0.020 INCH
			BOTTOM OF SCREEN: 93.5 FEET
30			BOTTOM OF WELL: 94 FEET
40			
50			
60			
70			
80			24-HOUR GROUNDWATER LEVEL: 84.3
90			GROUNDWATER LEVEL AT TIME OF DRILLING: 83.5
	BORING TERMINATED AT 94'		
100			



Logging Data

SHEET 1 OF ___

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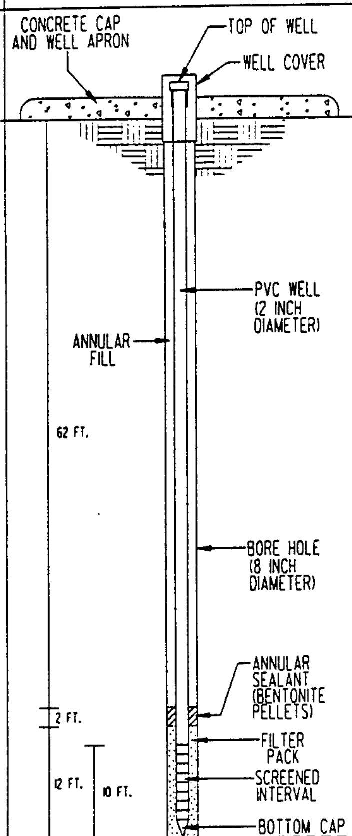
WELL/PIEZOMETER LOG

CLIENT: ARMY CORPS OF ENGINEERS		DATE	TIME	WELL NO.: MW-3
PROJECT NAME: FORT BENNING LANDFARM	STARTED:	10-23-95	10:30	WELL NO.: NORTH PORTION OF SITE
PROJECT NUMBER: 951349-01-05	COMPLETED:	10-26-95	12:00	ELEVATION (G.S.): 428.18
DRILLED BY: KILMAN BROTHERS				ELEVATION (T.O.P.): 430.37
LOGGED BY: KENT CAMPBELL				

ELEV. / DEPTH	DESCRIPTION	SKETCH	NOTES
0	ELEV. 428.18		RISER HEIGHT FROM G.S.: 2.2 FEET
			SIZE/THICKNESS OF APRON: 4 FOOT X 4 FOOT
			ANNULAR FILL: CEMENT GROUT
10			FILTER: 12 FEET SAND
			TOP OF SCREEN: 66 FEET
20			SCREEN LENGTH: 10 FEET
			SCREEN SLOT SIZE: 0.020 INCH
			BOTTOM OF SCREEN: 75.5 FEET
30			BOTTOM OF WELL: 76 FEET
40			
50			
60			
70			
	BORING TERMINATED AT 76'		
80			24-HOUR GROUNDWATER LEVEL: 65.75
90			GROUNDWATER LEVEL AT TIME OF DRILLING: 64.3
100			



Logging Data

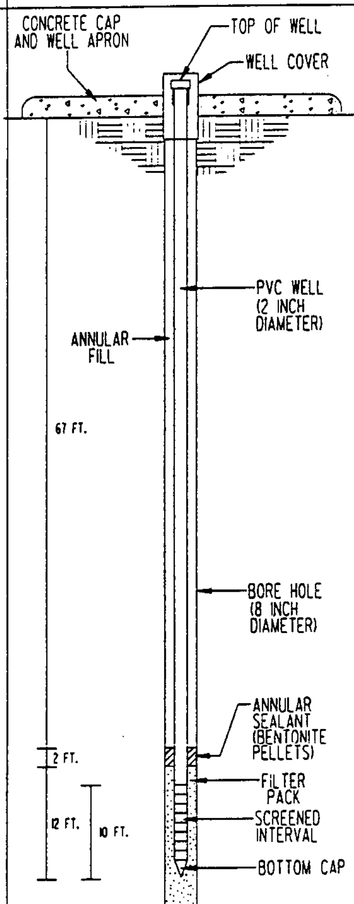
UNITED CONSULTING GROUP, LTD.

WELL/PIEZOMETER LOG

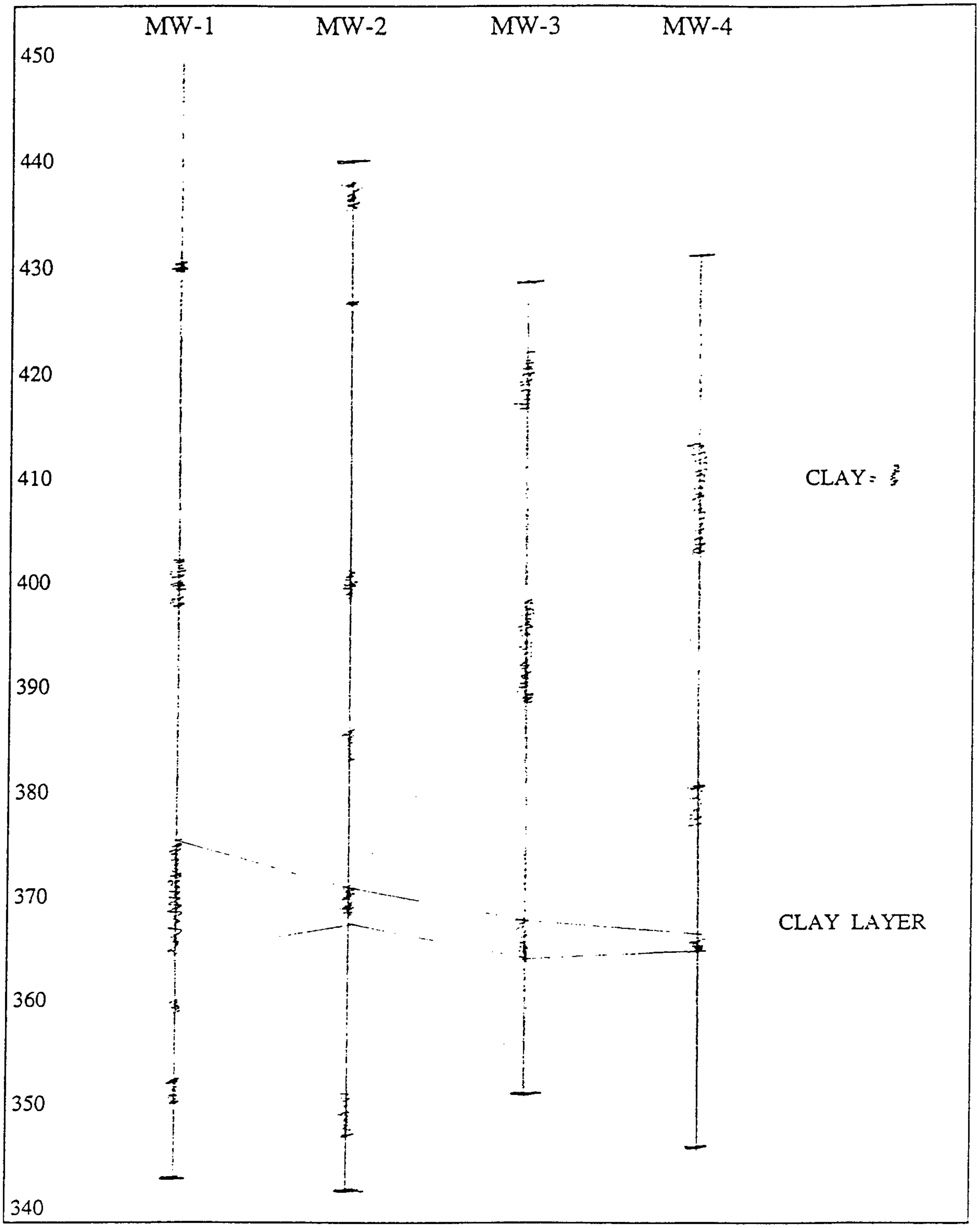
SHEET __ OF __

		DATE	TIME		
CLIENT:	ARMY CORPS OF ENGINEERS	STARTED: 10-25-95	8:45	WELL NO.:	MW-4
PROJECT NAME:	FORT BENNING LANDFARM	COMPLETED: 10-26-95	12:00	WELL NO.:	EAST PORTION OF SITE
PROJECT NUMBER:	951349-01-05			ELEVATION (G.S.):	429.50
DRILLED BY:	KILMAN BROTHERS			ELEVATION (T.O.P.):	432.40
LOGGED BY:	KENT CAMPBELL				

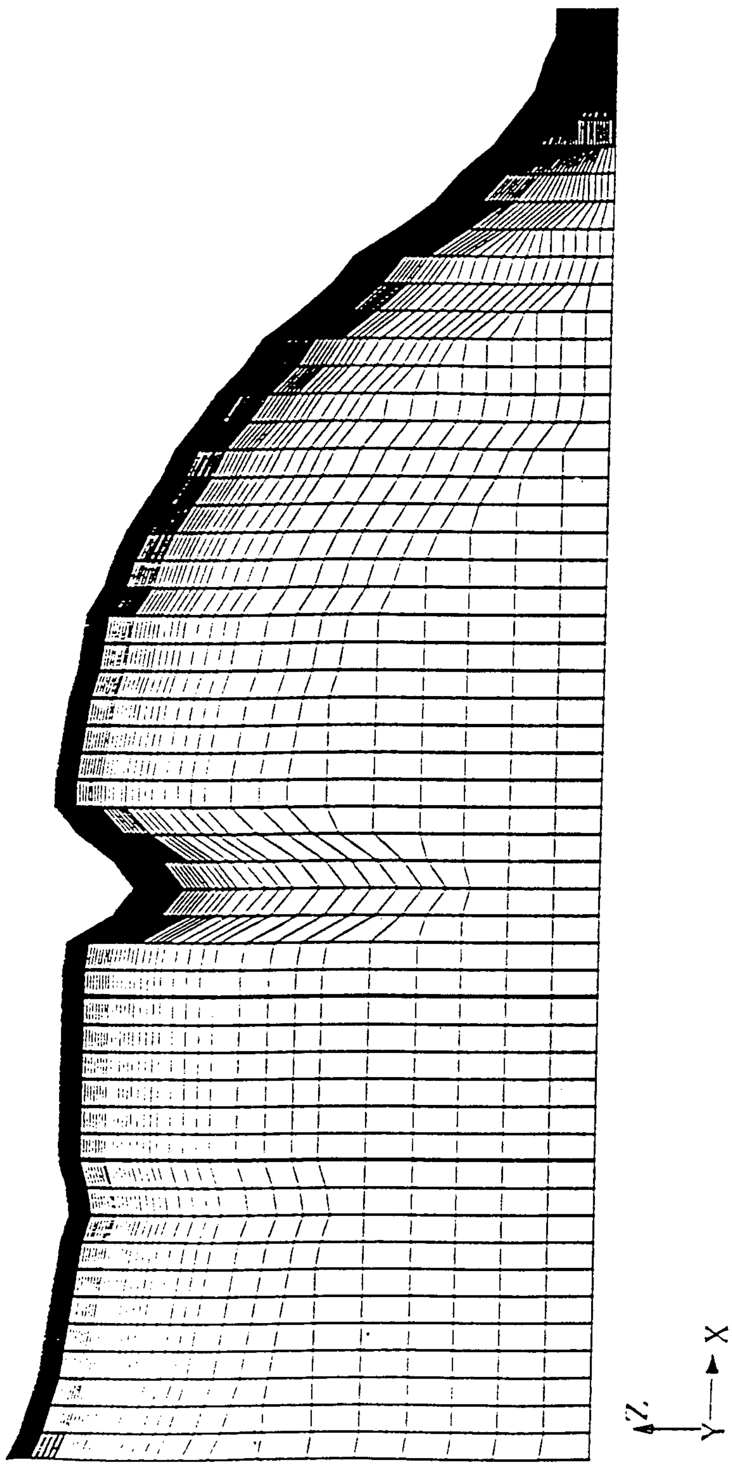
ELEV. / DEPTH	DESCRIPTION	SKETCH	NOTES
0	ELEV. 429.50		RISER HEIGHT FROM G.S.: 2.9 FEET
			SIZE/THICKNESS OF APRON: 4 FOOT X 4 FOOT
			ANNULAR FILL: CEMENT GROUT
10			FILTER: 13 FEET SAND
			TOP OF SCREEN: 71 FEET
20			SCREEN LENGTH: 10 FEET
			SCREEN SLOT SIZE: 0.020 INCH
			BOTTOM OF SCREEN: 81 FEET
30			BOTTOM OF WELL: 84 FEET
40			
50			
60			
70			
80			
	BORING TERMINATED AT 84		24-HOUR GROUNDWATER LEVEL: 72.35
90			GROUNDWATER LEVEL AT TIME OF DRILLING: 70
100			



Appendix U: Clay Layer



Appendix V: FEMWATER and LEWASTE Grid



The grid has been expanded by a factor of 10 in the z-direction.

Appendix W: Assumptions for Program Without Clay Liner

Femwater Assumptions:

1. Linear matrix equation solution indicator is solved by direct Gaussian elimination
2. material type = sand
   porosity = 0.3
   xx-component of saturated hydraulic conductivity tensor = 5.8×10^{-3} cm/s
   zz-component of the saturated hydraulic conductivity tnesor = $5,8 \times 10^{-3}$ cm/s
   yy-componentof the saturated hydraulic conductivity tensor = 0 cm/s
3. Density of water = 1.0
4. Acceleration of gravity = cm/s^2
5. Dynamic vicosity of wate = 0.013
6. Number of nodal points =2520
7. Number of elements =2420
8. Number of elements in the x-direction = 55
9. Number of elements in the z-direction = 44
10. Rainfall = 9.433×10^{-7} cm/s
11. No ponding is allowed
12. Number of Dirichlet nodal points (Discharge Nodes) = 7
13. Dirichlet-Head discharge values = 548.64 cm (18 ft)

Lewaste

1. Transient state
2. Distribution coefficient = 1.0×10^{-2}
3. Bulk density = 1.75
4. Longitudinal dispersivity - 2.13×10^{4}
5. Lateral dispersivity = 4.27×10^{2}

Appendix X: Assumptions for Program With Clay Liner

Femwater

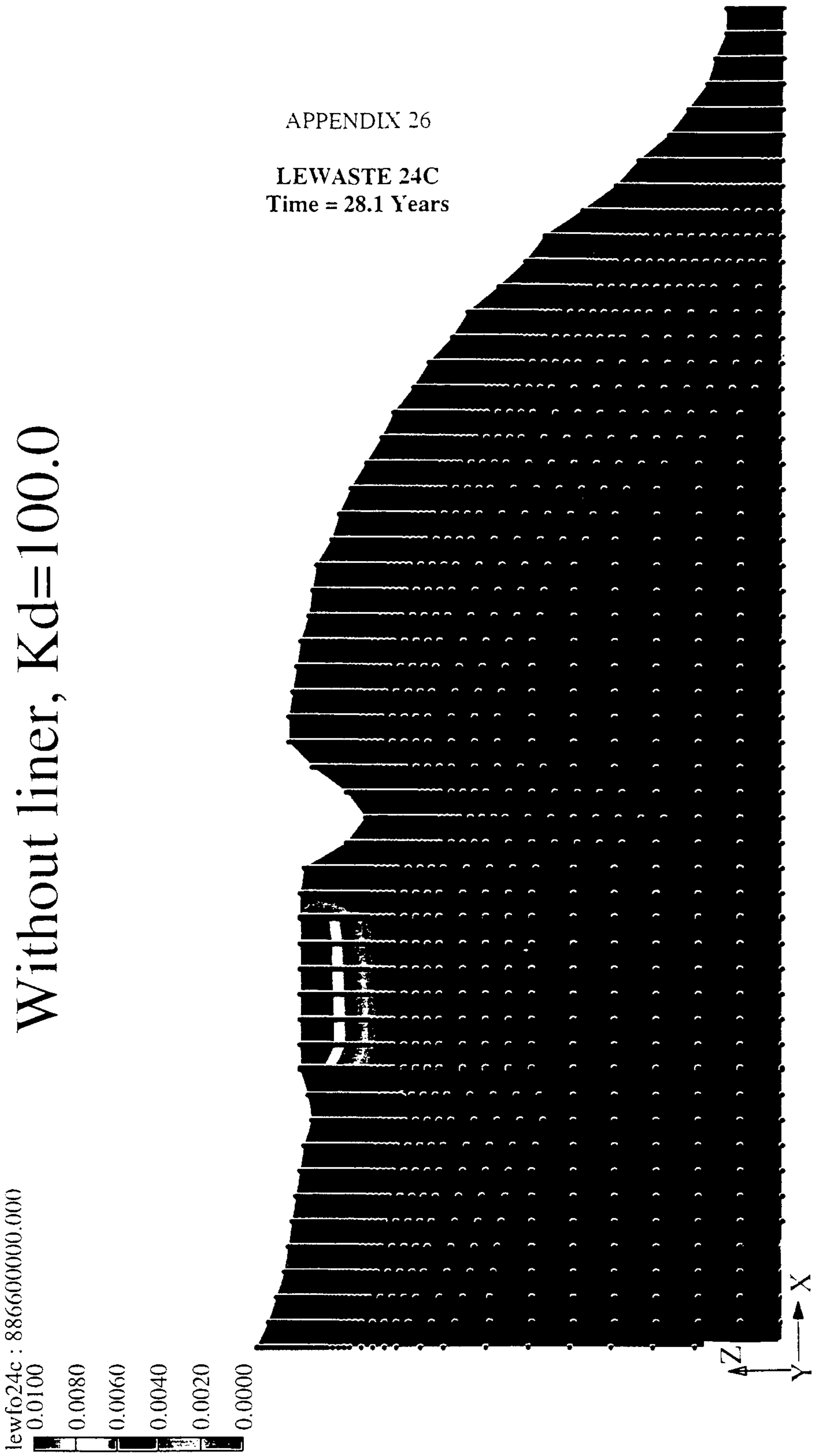
1. Material type = clay liner
   porosity = 0.45
   xx-component of the saturated hydraulic conductivity tensor = 9.00×10^{-8} cm/s
   zz-component of the saturated hydraulic conductivity tensor = 9.00×10^{-8} cm/s
   yy-component of the saturated hydraulic conductivity tensor = 0 cm/s

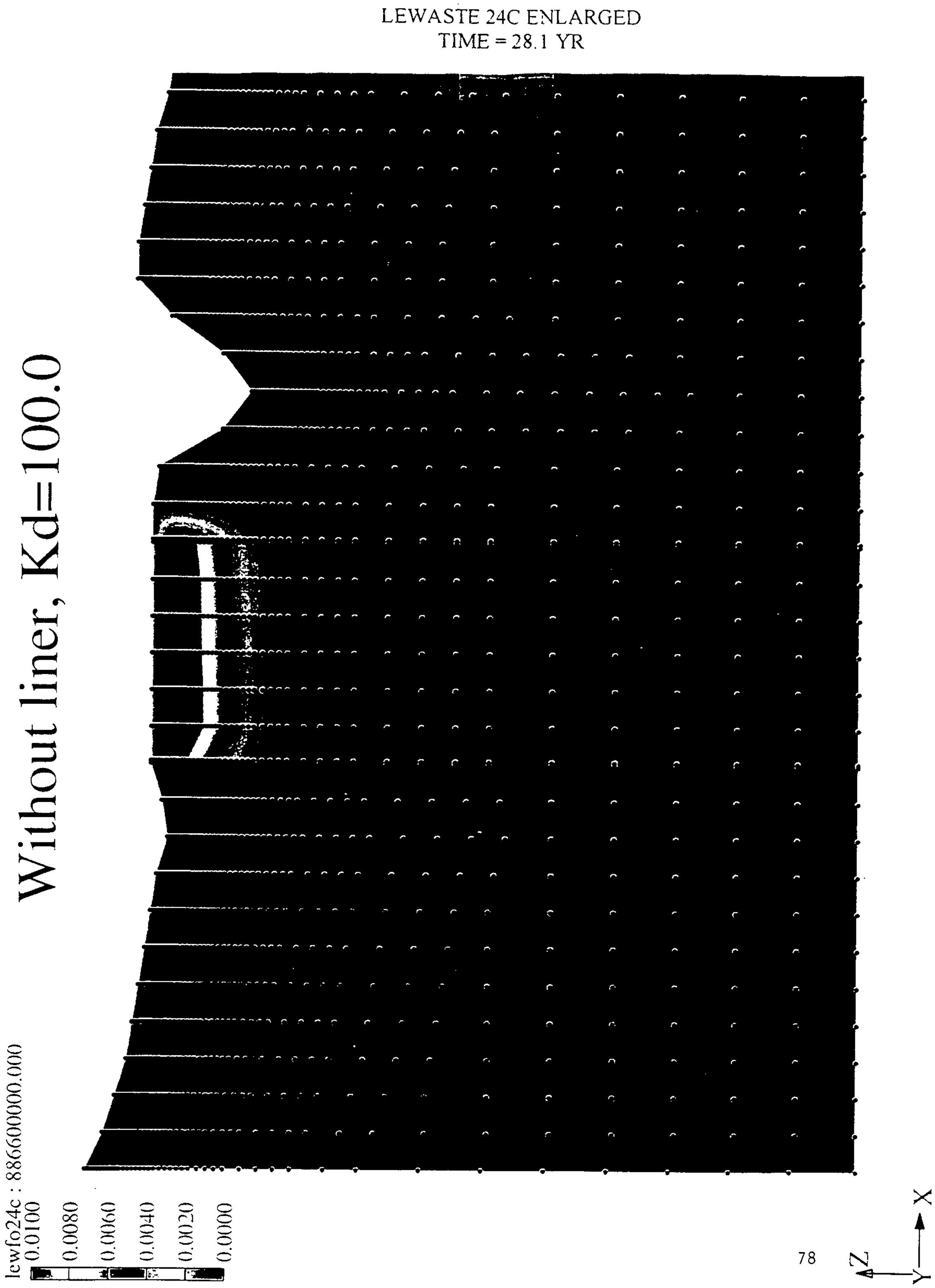
2. Material type = clay layer
   porosity = 0.45
   xx-component of the saturated hydraulic conductivity tensor = 9.00×10^{-5} cm/s
   zz-component of the saturated hydraulic conductivity tensor = 9.00×10^{-5} cm/s
   yy-component of the saturated hydraulic conductivity tensor = 0 cm/s

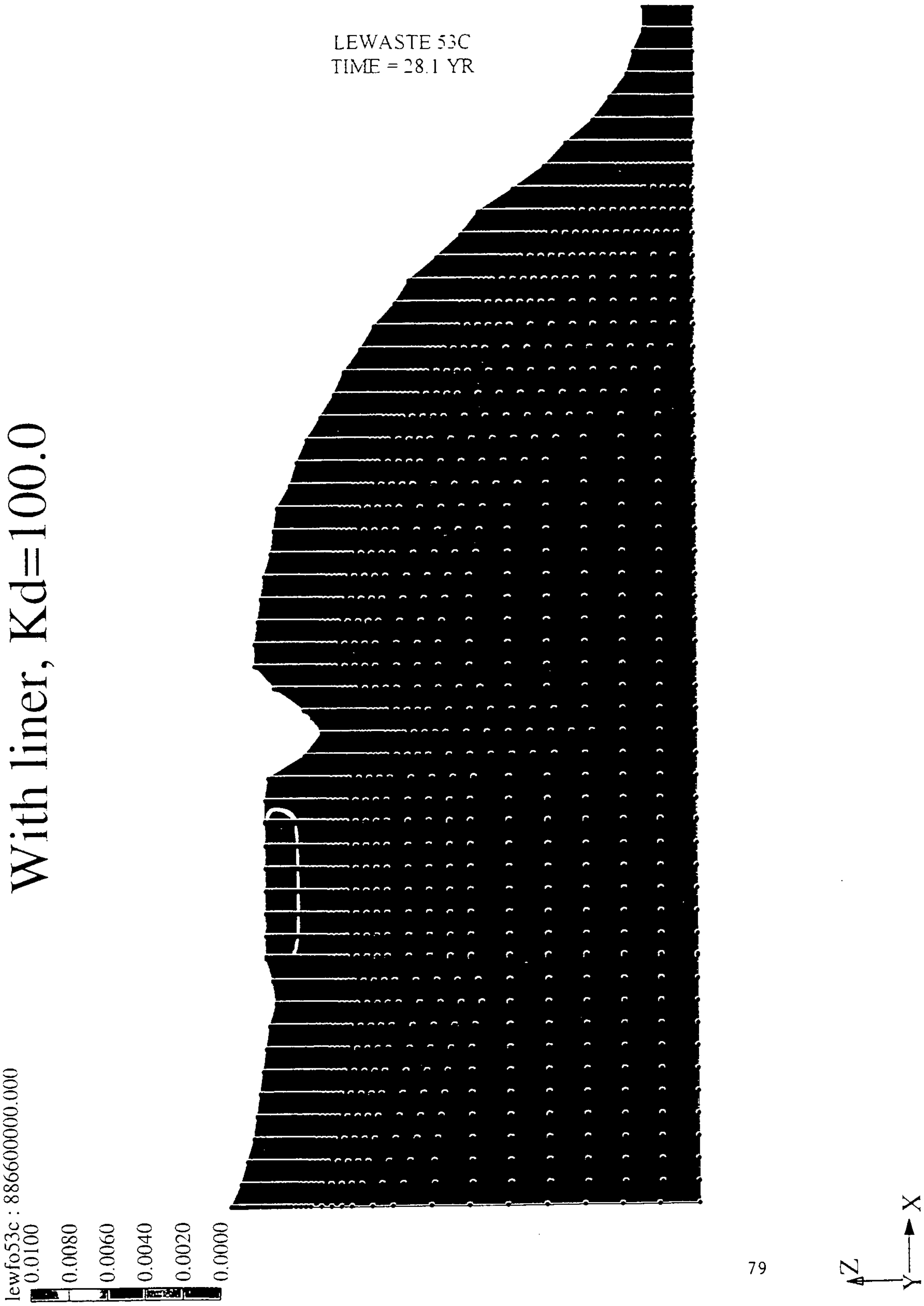
Appendix Y: LEWASTE Grids.

APPENDIX 26

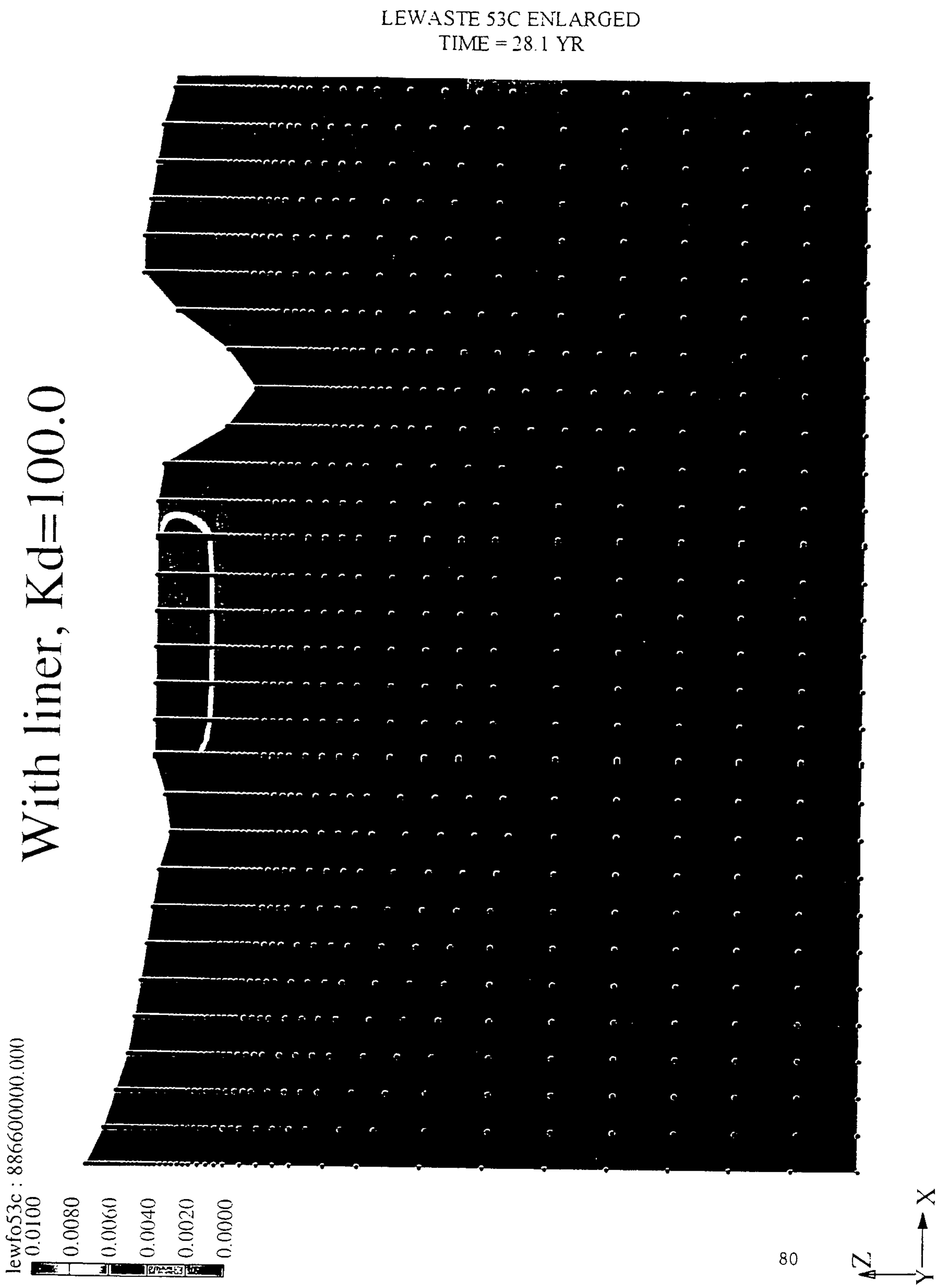
LEWASTE 24C
Time = 28.1 Years




LEWASTE 24C ENLARGED
TIME = 28.1 YR
Without liner, Kd=100.0
lewfo24c : 886600000.000
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
78
Z
Y
X



With liner, Kd=100.0


LEWASTE 53C ENLARGED
TIME = 28.1 YR
With liner, Kd=100.0
lewfo53c : 886600000.000
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
80
Z
Y
X

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ATTN: CERD-L

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